POWER PLANT ENGINEERING

Established Over 30 Years

VOL. XXX CHICAGO, JANUARY 1, 1926 No. 1

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Published on the 1st and 15th of each Month by the **Technical Publishing Co., 537 So. Dearborn Street, Chicago**
New York Office, 150 Nassau Street

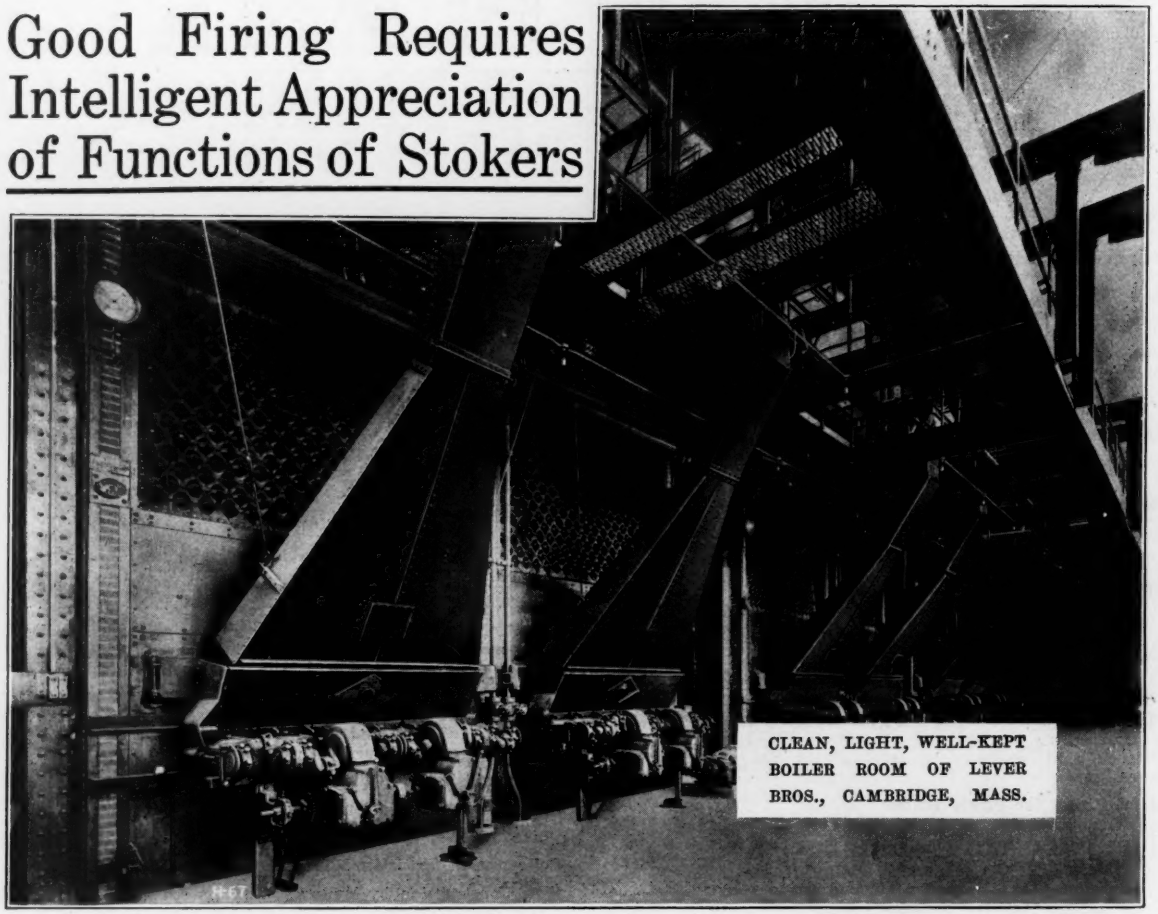
Subscription price $2.00 a year in the United States and possessions. Canada $2.75 a year. Other countries $3.50 a year. Single copies 15 cents. Copyright 1926, by Technical Publishing Co.

Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the act of March 3, 1879.

Member, Associated Business Papers, Audit Bureau of Circulations

Circulation of this Issue 23,900

Good Firing Requires Intelligent Appreciation of Functions of Stokers



CLEAN, LIGHT, WELL-KEPT BOILER ROOM OF LEVER BROS., CAMBRIDGE, MASS.

ESSENTIALS OF STOKER OPERATION ARE GOOD EQUIPMENT PROPERLY KEPT UP, ADEQUATE RECORDS OF RESULTS AND ATTENTION TO FUEL BED, AIR SUPPLY AND ASH PIT CONDITIONS. BY R. SANFORD RILEY *

STOKER users and stoker manufacturers are equally interested in the subject of good stoker operation. The part played by the purchaser is most important but, unfortunately, the purchaser does not always take the trouble to do himself justice. The price question frequently looms up out of all proportion to the real end in view which is the smooth and economical operation of the entire plant. Stoker manufacturers try their best to educate the customer to his real needs and most of them can now place a wealth of experience and data at the customer's command. Nevertheless, the customer may be too much influenced by his financial situation at the moment, hence is likely to buy inadequate, low-priced apparatus. This word of caution is not necessary for experienced buyers of such apparatus but cannot be too strongly emphasized for the average industrial plant. The old saying that "the best is none too good" applies strongly here and it should also be remembered that the best goods generally cost more because they are worth more.

GOOD EQUIPMENT IS OF FIRST IMPORTANCE

The first point to be observed, then, is proper equipment. If owners recognized the fact that the uninterrupted operation of their whole plants hinges on their boiler rooms, they might be more inclined to give the equipment the attention it deserves. Fortunately owners, generally, are coming to recognize the importance of their boiler rooms, hence we see a gradual toning up and higher standards are being adopted both in regard to equipment and operation. Rise in the cost of coal has had a good deal to do with this and the growing tendency to keep costs at a minimum has also contributed.

This is not the place for a discussion of the different kinds of stokers or combustion apparatus, beyond pointing out its importance. All the standard stokers of today have been through a process of evolution and development which makes them efficient and reliable when properly applied. The varied operating conditions and different kinds of coal indicate the kind of equipment which should be used. Here is the place for good judgment on the part of both the owner and his advisers. The stoker manufacturer should be consulted freely because it is to his interest to recommend the right kind of apparatus for the particular needs. In this article we deal with stoker firing but, of course, cannot ignore the kind of apparatus and the way it is installed.

Auxiliary apparatus should be considered in much the same way. It should be adequate and the best of its kind. The question of automatic regulation is answering itself by the gradual development of first-class apparatus, which is now a great help in operation. It should be remembered that automatic regulating apparatus itself requires regulation and such regulation is not so simple as the direct regulation of coal and air. No regulator can think for itself and the installation of an automatic regulator with

* President Riley Stoker Corporation, Worcester, Mass.

the idea that it will take care of itself is sure to make trouble. This is the sort of thing which gets good apparatus condemned. The stoker and all its connections may be condemned because a piece of regulating apparatus is expected to think for itself. Fortunately we are getting more and more boiler room operators who are able to think and use apparatus for the purpose for which it is designed.

Attendance Should Be Intelligent

Nowhere is the improvement of personnel and morale more evident than in the modern boiler room. The old idea was to put the brains in the engine room and let the boiler room run itself with any kind of help that had the necessary muscle. Now we all recognize that the engine room equipment has possibilities which are relatively easy to secure. The possibilities are determined more or less accurately in the designing office and the operator can supply the conditions.

On the other hand, the possibilities of the boiler room are much more elusive and, therefore, have to be studied continuously. Fortunately the rewards are worth while, so we see a constantly improving personnel and a constantly higher standard of requirement in boiler room operation. In this respect stokers are indebted to the development of pulverized fuel, because pulverized fuel demands greater care than was formerly considered necessary for stokers. Stokers could be abused and neglected, whereas pulverized fuel equipment will not stand the same laxity without showing results that command attention. This care applied to stokers is moving them onto a higher plane of efficiency so that what were formerly considered special test results are now demanded in every day service.

Adequate Instruments Are Needed to Show Operating Results

We cannot emphasize too strongly the debt we owe the makers of recording and observation instruments. Such instruments used to be considered a luxury but now are very properly considered an essential part of any first-class boiler room. We now see temperature and CO_2 recorders, steam and water meters and coal-weighing and recording apparatus used in the boiler room in a way that is more or less comparable with the use of calculating and bookkeeping machines, card systems and all the other requirements by which the front office keeps track of costs. The executive or engineer who does not keep track of boiler room performance and costs has no place in modern competitive organizations.

It Pays to Keep a Plant Clean and in Good Repair

Another important factor is the cleanliness of the boiler room. Nothing is gained by the accumulation of dust and dirt that was formerly taken as a matter of course. This influence on morale cannot be computed but is being recognized as a big factor in efficient operation. Again we are indebted to the development of pulverized fuel for the enforcement of standards that will help the stoker onto a higher plane.

The appearance of the stoker itself has changed so that it is a better looking piece of machinery. With this has come the willingness and obligation to keep it clean and ship-shape. Formerly there were too many repairs of the "baled-hay-wire" type, but this is now superseded by a well-kept stoker that looks to be what it really is, viz.—a highly developed machine for feeding and burning coal.

That old adage of "A stitch in time saves nine" never applied more strongly than it does to stoker equipment. The stock of repair parts and the way they are kept is frequently the most characteristic feature of a modern boiler room. An indiscriminate pile of new or old repair parts generally indicates sloppy operation and poor economy. On the other hand a well-equipped and classified stock room means the minimum of delay and the best possible condition of the stokers. A photograph of a modern stock room is shown in Fig. 1. This kind of a stock room means dividends to the owners because no plant can afford to neglect the stitch that saves nine in the boiler room.

Here, also, we cannot emphasize too strongly the need of properly made spare parts for stokers. By all means go to the maker for these parts—not only because he knows what is required but also because of improvements that are constantly being made. The stoker manufacturer has access to the records of hundreds of companies operating his equipment. He carefully tabulates each item sold for repairs and tries to eliminate, by changes in design, the necessity for frequent renewals for any particular part.

FIG. 1. CLEAN, WELL-ARRANGED STOCK IS THE FEATURE AT THE STAMFORD GAS & ELECTRIC CO.'S STOCKROOM

All progressive stoker manufacturers make improvements in the details of their stokers and are careful to make these improvements applicable to stokers already in use. When an improved detail is evolved, either from a stoker engineering staff or from a customer, it is a subject of earnest study to make this improvement so that it can apply to all present stokers. Sometimes it takes a good deal of ingenuity to make these details so that they can be used on old stokers as well as new ones and this is something of which the customer should take advantage.

Unfortunately, some customers have the idea that the price per pound is a proper measure of cost of repair parts. A price per piece would be less inaccurate, but even this would not insure up-to-date design or proper material. Obviously a price per pound is a direct incentive for the jobbing foundry to make the heaviest pieces possible in order to give the appearance of low cost. The jobbing foundry also has no incentive to improve parts even if it had the necessary skill and experience. It is, therefore, good policy from both an operating and a maintenance point of view to buy repair parts directly from the maker of the stoker.

To help customers along this line, most progressive stoker manufacturers have a service department or its equivalent. The object of this department is to make periodical inspections to see that the stokers are getting a fair deal. This, of course, includes giving the customer a fair deal also, even though he may not appreciate his need at the time. When customers realize more generally that it is to their own interest to keep their stokers in perfect condition and supplied with up-to-date parts we shall see a still further advance in boiler room economy.

The Operator Should Study His Stoker

Having considered correct application and installation of stokers, we may now take up briefly some specific points that deal with stoker operation.

FIG. 2. RELIABILITY IS ESSENTIAL WHEN ONE BOILER AND STOKER CARRY THE WHOLE LOAD. NOTE THE BUSINESS-LIKE APPEARANCE OF A MODERN PLANT

Let us assume that the operator has had placed in his charge a new stoker. As with any piece of machinery, the first thing to do is to see that it is properly lubricated and thereafter to see that this duty is regularly performed. The operator should then endeavor to become familiar with any points in the design of the stoker which he is to operate which have been put there for certain purposes. For instance, the adjustment for changing the rate at which the coal is fed through the furnace, air control, proper use of clinker grinder where one is installed and any other features applying to the particular type of stoker which is to be used.

In our consideration of the essentials of good firing, it may be helpful to point out which losses are affected by operation and which can scarcely be altered once the management has placed in the hands of the operator a certain set of conditions represented by the stoker, furnace and boiler, and the grade of coal selected.

The losses over which the operator has little or no control are: 1. Loss due to moisture in coal. 2. Loss due to water formed in burning the coal. 3. Loss due to radiation.

We will assume that the design of boiler, furnace and stoker is such as to bring the above losses to a point consistent with modern, good practice. From there on, the operator plays an exceedingly important part and it is his interest and skill that will get the most out of the stoker, for his indifference can only result in a manner of operating that will fail to bring about the efficiency and economy that can rightfully be expected.

The operator is, therefore, a most important factor in securing combustion efficiency and the amount of the following losses is largely up to him, that is, over and above a certain minimum figure: 1. Loss due to heat in flue gas. 2. Loss due to incomplete combustion, CO. 3. Loss due to combustible remaining in the ash.

Good stoker firing is aimed at keeping these losses at a minimum so that we may now consider some of the points that should be watched.

Draft and Excess Air

In burning fuel on the grates and in passing air through the fuel bed it is always necessary to use some extra or "excess" air. Conditions in a furnace can be regulated, in some cases, to cut down this excess air to a relatively small amount but it can never be entirely eliminated.

When the fuel contains but little volatile matter, as is the case with anthracite coal and coke breeze, it is comparatively easy to operate with a slight amount of excess air. Almost all of the air supplied to the thicker parts of such a fuel bed is used in combustion. Where the fuel bed has thinned down until it is practically ash, however, some excess air will be necessary.

With bituminous coals containing a large percentage of volatile matter, the amount of excess air will be greater. As the hydrocarbons distill off, they are burned above the fuel bed, getting their air from that which has passed through the fuel bed. It is apparent that the mixing of gases necessary for combustion cannot be perfect for all of the particles of oxygen cannot be brought into contact with the particles of the hydrocarbons which would result in complete combustion. This means that excess air is necessary for burning these combustible gases. In general, 25 to 50 per cent excess air represents good operation and more than that poor operation.

Under all conditions of operation there should be a slight suction in the furnace and under no conditions should there be a pressure. Suction over the fire should be as near 0.05 in. water gage as possible during normal operation. If the suction is over 0.25 in., infiltration losses will be so great as to defeat economical operation. If a pressure is maintained in the furnace, it is liable to ruin the stoker and brick work. Where automatic regulators are used, the correct draft can be maintained by manipulating the flue or stack dampers in conjunction with the forced-draft, air-duct dampers. Unless all dampers, air ducts and flues are kept in good condition, it will be impossible to maintain the proper draft for ideal combustion.

Pressure under the grates will depend upon the coal used, the thickness of the fuel bed and the rating desired. By observing the condition of the fire, it is not difficult to determine the draft that will produce the most efficient

results. Draft gages and recording instruments will be found helpful in this connection. The lowest pressure that will give the correct mixture of air and fuel should be used at all rates of combustion. This is necessary so that each particle of combustible may be reached by the proper amount of oxygen.

When the conditions demand more steam, both air supply and coal feed should be increased, and vice-versa. Never control the steam output by the air supply alone, as this will give a gas producer effect, wasting unburned gases and coke.

As a rough method of checking the air supply, the flame at the top of the first pass can be observed. With certain coals and the proper air supply, the flame will die out just about the time the gases leave the first pass, while, if too much air is supplied, the flame will die sooner, or if an insufficient quantity is supplied, the flame will be carried back through the other passes. Smoke from an underfeed stoker usually denotes a lack of air.

Co—Incomplete Combustion

After a certain point is reached, decreasing the excess air increases the loss from incomplete combustion as indicated by CO in the flue gas. Now, the burning of a pound of carbon to carbon monoxide liberates only 4450 B.t.u., while the burning of a pound of carbon to carbon dioxide, liberates 14,600 B.t.u. When CO is formed, only 31 per cent of the possible heat is made available. It is evident, therefore, that even a small amount of CO indicates comparatively large losses from incomplete combustion.

Decreasing excess air also decreases the volume of stack gases so that the heat loss in flue gas is reduced. Increasing excess air produces opposite conditions so that it is a question of balancing a loss against a gain and operating with the amount of excess air which is determined to be most economical. Excess air should, therefore, be cut down until losses from incomplete combustion become too great. By observing CO_2 readings and watching the fire, the operator can, by experience, learn to judge from the appearance of the flame and fuel bed, the proper operating condition.

Unwanted Air Should Be Barred Out

Leakage of air through the boiler setting is common and too much emphasis cannot be placed on seeing that the setting is tight, that dampers fit and every precaution is taken to keep out all air except that which is admitted where and when it is wanted for combustion purposes.

The fuel bed should be kept as uniform as possible and care exercised to see that holes are not allowed to develop in it. The reduced resistance to the passage of air offered by a small hole in the fire will rob the rest of the fuel bed of some of the air it should get and thereby cause trouble all out of proportion to its size. The side and bridge walls should be kept free from clinker accumulations.

Watch the Ash Pit, Banking and Coming Load Demands

Another factor entering the question of high CO_2 is the ash pit loss from combustible in ash. This, again, must be balanced against the other losses to make the sum of all boiler losses a minimum. It is possible to boost the CO_2 figure by carrying too heavy a fire at the dump end of a stoker, but this gain in CO_2 is more than offset by loss in the ash. The fire near the dump should be kept uniform and not too heavy so that the combustible in ash will be kept as low as consistent. The present tendency toward long stokers is helping considerably in this respect.

The ash pit should be kept tight so that air will not leak through the lower end of the stoker. Also, it is important to see that it is emptied before it becomes so full as to cause trouble.

Where economy is the chief consideration, the rating at which the stoker will give maximum efficiency should be determined and then each unit should be operated at as near the maximum efficiency as possible. Banking losses should be kept as low as possible by keeping on bank only as many boilers as are needed to meet such demands as may reasonably be expected.

Where fluctuating loads are the rule, a little foresight in looking ahead to meet changing conditions will result in substantial savings as well as making the work of the operator easier. For instance, the fire should be built up to meet expected peaks and the fuel bed allowed to burn down just previous to cleaning time.

In stoker firing, the goal to strive for is to obtain results under every-day working conditions that are as close as practical to those theoretically possible. Then the best interests of both user and maker of stokers will be served and each will be doing his part in helping to conserve one of our greatest natural resources—coal.

The chart following sums up, in concise manner, the points brought out and may well be posted in the boiler rooms.

Good Stoker Firing Involves Consideration of

Economy		Operating Conditions	Type or Design of Stoker
Fuel	**Maintenance**		
Operate at as near ratings of maximum efficiency at all times as possible.	*Stoker*	Anticipate conditions. Build up fires to meet peaks. (Reduce when over.)	Study design of stoker — make use of features provided to facilitate operation, such as:
Avoid excessive number spare boilers on bank.	Keep machine lubricated.	Have grate well covered when banked and keep fire clean.	Stroke adjusters.
Reduce Losses Due to	Keep machine clean.	Keep all instruments in working condition as a guide to economical firing under normal ratings.	Rocker dumps.
(a) Heat in flue gases (carry high CO_2).	Keep machine in good state of repair.		Air control.
(b) Incomplete comb. (CO).	*Furnace*		Clinker grinders.
(c) Loss in combustible in ash.	Do not carry higher ratings than necessary (due unanticipated outage of other units).		
Keep fires clean, side walls and bridgewall free of clinkers (shorten cleaning periods).	Always operate with draft (not pressure) in furnace.		
Change conditions of fire with changes in load.			

Stoker Operation by Modern Methods

TRAVELING GRATE, UNDERFEED AND OVERFEED TYPES PRESENT DIFFERENT PROBLEMS IN HANDLING

METHODS OF STOKER operation must be governed by the type installed. In general, there are three main types of mechanical stokers, namely: traveling grate, underfeed and overfeed. The first and third types are sometimes, in older installations, operated with natural draft but, since forced draft is being used in a majority of cases, it is deemed advisable to discuss stoker operation on this basis.

In general, underfeed and overfeed stokers are nearer alike in operation than is either one to the traveling grate.

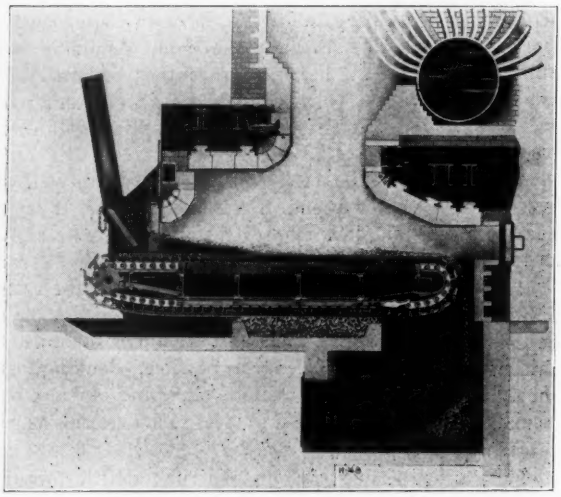


FIG. 1. SHOWS DETAILS OF A TYPICAL FORCED BLAST, TRAVELING GRATE STOKER INSTALLATION

Under the term traveling grate are included all those stokers having revolving grate surfaces, whether technically called chain-grate or traveling grate.

Traveling Grate Stokers

Operation of this type is similar to a flat endless belt, revolving around two drums. Usually, by means of overhead bunkers, coal is directed to the stoker hoppers, passes under the feed-gate which controls the fuel-bed thickness, and, after burning, the ash is discharged into a pit. A typical traveling grate stoker installation is shown in Fig. 1.

To start a fire, set the feed-gate to give a fuel bed thickness of 4 to 5 in. and then run green coal onto the grate for a distance of about 4 ft. Next, through the side doors, throw in wood and oily waste or rags on top of the coal. Ignite this material with the stack damper and air valves slightly open and without forced draft. As the coal becomes thoroughly ignited, the natural draft should be increased by gradually opening the stack damper and air valves. Now, start the stoker at the lowest speed and gradually apply forced blast. Before starting the fan, close the air valves in each compartment and then open them only as the fire progresses over the corresponding air zone. Care must be used at this point or too much air will dull the fire and retard combustion.

Mid-western coals—Illinois, Indiana and western Kentucky—ignite more readily than Ohio, Pittsburgh and Eastern coals, such as Pocahontas, New River and Georges Creek. Low grade bituminous coals of Colorado and Iowa and the Western lignites will not ignite at all at the front of the stoker, because of the large percentage of moisture which must first be driven off. Anthracite ignites more slowly than bituminous coal and additional time must be allowed for the fire to work down through the fuel bed before applying forced blast. Coke breeze, unless containing an unusual amount of volatile matter—6 to 8 per cent—will not ignite in a cold furnace and the refractories must first be heated with a coal fire.

FUEL BED THICKNESS

Fine grades of anthracite are usually burned with greatest success on traveling grate stokers but, because of their greater resistance to air flow, these grades of coal should have fuel beds thinner than for bituminous coals. Anthracite fuel beds should vary from 4 to 6 in., while bituminous coals may have a fuel bed thickness of 6 to 10 in. Coke breeze beds should be from 5 to 7 in. thickness.

No absolute rule can be given for the thickness of the fuel bed with any kind of fuel but it should be such as to give the best results for the particular load and operating condition of the boiler unit. The fire should be thick enough so that changes of load during the day can be taken care of by changing the grate speed, leaving the gate height constant. In general, a thick fire and slow speed give better results than a thin fire and high speed.

With light loads, a short fire should be maintained. It is not necessary to cover the entire grate surface as with a natural draft stoker. The speed and depth of fuel bed can be adjusted to allow the fuel bed to burn out before reaching the end of the stoker. In this case, no air at all is supplied to the rear part of the stoker, which simply conveys the ash to the pit. This applies to all bituminous coals, lignite and coke breeze. With anthracite, however, the fire should be kept long so as to do as much of the burning as possible under the rear arch.

FURNACE DESIGN IS A FACTOR IN OPERATION

One of the most important factors in the successful operation of traveling grate stokers is the furnace design.

In some of the older installations water-backs are still in use. The two types of water-backs are commonly designated as low and high pressure. With the first, water is often supplied by the city water system or some other similar source. With the high-pressure system, the water-back pipes are connected to the boiler tubes and require no special attention except blowing out scale once in a while. With the low-pressure system it is important that circulation be assured before firing.

High percentages of overload and resulting high furnace temperatures have made some sort of side wall cooling necessary. Where pipes are provided for water cooling, similar methods of water supply are employed as with water-backs and the same points must be observed. Another method of side wall cooling is by the use of air-cooled refractories which will be discussed in more detail in another place.

Even where water-backs are connected to the boiler tubes and there is no trouble with the burning of these

pipes, satisfactory results from a combustion viewpoint are not obtained and modern installations of traveling grate stokers are being provided with rear arches. A typical example of rear arch construction is shown in Fig. 1. In Fig. 2 is shown a traveling grate stoker installation with a water-back at the rear. The original purpose of this water-back was to scrape any unburned fuel off the top of the ash going over the rear and also to provide a seal against the infiltration of air into the combustion chamber. The effect of this excess air is shown in Fig. 2. But a seal was seldom, if ever, provided and, if the ash were allowed to pile up on the water-back, clinker formed on the tile above the water-back to such extent that it often stopped the stoker.

Another serious defect of water-back installations was the inadequate protection of the ends of the links or clips from the radiant heat of the furnace. Reflection of this heat onto these links, just at the point where the flat surface was broken when it passed around the rear end of the stoker, burned the ends severely on the upper corners.

With these defects and no appreciable commendable points, water-back installations are going into the discard and the modern traveling grate stoker installations are being provided with rear arches not only to prevent burning of the links but to crowd the excess air from the rear

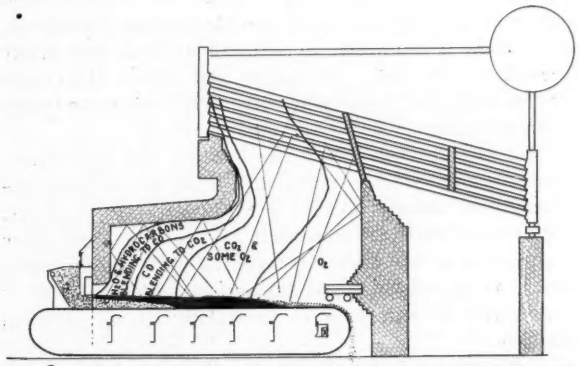


FIG. 2. THIS TRAVELING GRATE STOKER HAS A WATER-BACK TO KEEP UNBURNED FUEL FROM THE ASH-PIT

forward into the path of the combustible gases. This is shown graphically in Fig. 3.

Referring again to Fig. 1, the cinder seal underneath the stoker, just in front of and above the rear ash pit is made of fine ash or cinders packed in until the grate surface drags through this material when passing above it. A good seal at this point is quite important for, even with a rear arch, if there is no cinder seal, there is nothing to prevent air from passing under the stoker and up into the furnace. This air will hug the bridge wall and pass into the tube bank without properly mixing with combustible gases. Such a seal is more important with natural than with forced draft, as air needed for combustion will follow the lines of least resistance and will pass around the rear of the grate instead of through the fuel-bed where it should.

Ignition Is Effected by Arches

One of the difficult problems met in the use of traveling grate stokers is to secure ignition. This is particularly difficult for fuels low in volatile matter and relatively high in ash, such as coke breeze and small sizes of anthracite. In contrast to the agitation occurring in the fuel-beds of underfeed or overfeed stokers, the fuel bed of a traveling grate stoker lies perfectly quiescent and the film of carbon dioxide around each of the upper fuel particles tends to prevent further ignition. Consequently, a refractory surface above the fuel-bed must be provided to reflect heat back to the fuel bed, with sufficient force to penetrate the carbon dioxide and ash films which envelop the fuel particles. This refractory surface is known as the ignition arch. Space does not permit much discussion of arches, but the more important points are length, height of the grate, location with reference to the tube bank so as to permit maximum radiation from fuel-bed to tubes, and width of throat between front and rear arch.

Some designs of traveling grate stokers have a drying zone just in front of the gate which controls the supply of fuel. In one case furnace gases are drawn down through

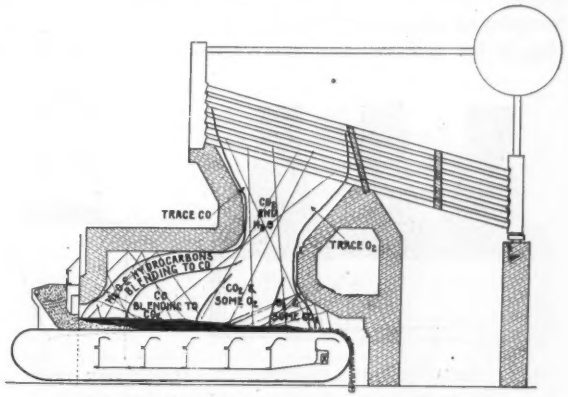


FIG. 3. SUSPENDED REAR ARCH FORCES EXCESS AIR FROM THE REAR INTO THE COMBUSTION ZONE

the fuel bed at this section of the grate, thus drying and heating it ready for rapid ignition as soon as it passes beyond this zone.

Speed and Air Control

Flexibility of speed control is one of the most important points in the successful operation of this type of stoker. The stoker is driven either by a ratchet wheel and pawl, or by a worm gear, the former giving intermittent, jerky movement to the grate while the latter gives continuous travel. Where a worm gear drive is used, the best sources of power are a direct-connected steam engine or an electric motor. With electric power, either alternating or direct current may be used, although the latter gives more flexibility of control.

The average rate of travel of this type of grate surface is from 1.5 to 6.0 in. per minute. Higher speeds are sometimes employed but only where unusual conditions prevail.

Fuel Sizing and Distribution

Bituminous coals and lignites used on traveling grate stokers should be crushed to a size where all will pass through a 1¼-in. round mesh screen. With coke breeze all should pass through a ¾-in. round mesh screen, with not more than 20 per cent through a $\frac{3}{16}$-in. round mesh screen.

Small sizes of anthracite are, of course, governed by the standard specifications for the particular grade used.

Precaution must be taken to obtain uniformity of coal on the grate. With 1¼-in. screenings, the largest lumps will be of this size, while most of it is generally of particles no larger than ½-in. diameter.

Care must, therefore, be taken in the method in which the fuel is fed to the stoker hopper. If it is allowed to avalanche out of a round spout or spouts suspended above the hopper, the fuel will probably form in peaked up piles with the larger lumps thrown to the outside and the fine material in the center. This will cause a distinct segregation of fuel particles in the fuel bed. A number of plants have experienced this difficulty, which not only affected combustion conditions but gave rise to other troubles. In one case, the fuel was fed to the hopper through three round spouts with the ends flared in bell shape, as shown in Fig. 4.

This segregation of fuel particles caused two distinct streaks or grooves down the center of the fuel bed and also a streak along each side. The streaks or strips along the side in which the fuel was burned down near to the grate were not so noticeable as those in the center, since combustion in the fuel bed is usually more complete along the

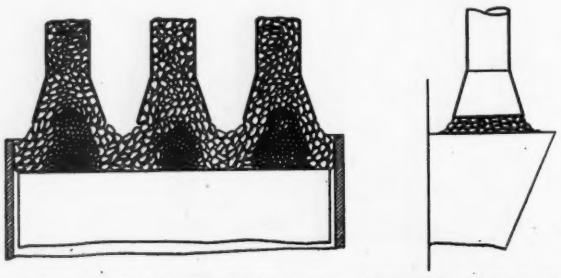


FIG. 4. ROUND SPOUTS DISCHARGING ABOVE THE LEVEL OF THE FUEL HOPPER DISTRIBUTE FUEL LIKE THIS

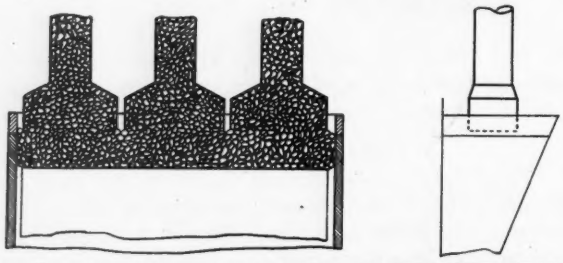


FIG. 5. FLATTENED SPOUTS DISCHARGING BELOW THE LEVEL OF THE FUEL HOPPER GAVE IMPROVED DISTRIBUTION

sides than in the center. This is due to greater air leakage and more rapid burning. The grooves in the fuel bed on either side of the center spout were distinctly noticeable but operators did not realize what was causing them nor did they connect the cause of these grooves with another and even more serious difficulty—that of arch erosion.

Air naturally follows the lines of least resistance and will accordingly pass through the fuel bed along points where the fuel particles are coarsest. This obviously causes a greater evolution of gas along the strips of coarse fuel. So much gas is generated above these narrow strips that complete combustion of much of this gas is not effected until it strikes the arch. This causes higher temperatures just above the strips of coarse fuel than at other points, with a resulting softening of the arch. With these longitudinal strips of the arch softened by the high temperature and a greater density of gas along these lines it is quite easy to see what would cause distinct grooving or erosion of the arch as the gases sweep around the end.

Remedy for this trouble was quite simple and it was only necessary to alter the method of supplying fuel to the hopper. This was done by removing the round, bell-shaped flares on the ends of the spouts and substituting sections which were flattened out as shown in Fig. 5, allowing more fine particles to be dropped across the width of the stoker. In addition, the sides of the fuel hopper were extended above the old level, so that the ends of the spouts would be covered at all times, if the hopper and the spouts were kept filled all the way up to the bunker above. In this way, the larger lumps did not roll to the outside and there was no distinct segregation.

After the fuel spouts were changed, a marked improvement was noted all around. There was less carbon in the ash, a better quality of furnace gas and no appreciable erosion of the arch.

Segregation may also be eliminated by swinging spouts, either hand or automatically operated, or by installing a screw type of spreader.

Tempering Coal by Adding Moisture

Eastern bituminous coals, such as Pocahontas, New River, Clearfield and Georges Creek, as ordinarily received, contain too little moisture to be burned properly on traveling grate stokers. Consequently, it is necessary to temper these coals by adding moisture to such extent that they will contain 6 to 8 per cent. Unless this is done, these coals will puff up into hard cauliflower-like formations, which make it impossible to obtain a uniform flow of air through the fuel bed. Pittsburgh and certain Ohio coals are also somewhat of the same nature and must be tempered to contain about 8 to 10 per cent moisture.

Mid-western coals, being free-burning and non-caking, require less tempering, particularly since, as ordinarily received, they already contain 8 to 10 per cent moisture. Where these coals are somewhat dry, however, and there is an excess of fine material, traveling grate stoker operation is improved by slight tempering. Adding water is particularly advantageous in preventing sifting of small particles.

Tempering is best accomplished by wetting the coal at the crusher, or as it is being put into the crusher. This gives the water more time to mix intimately with the coal. If this cannot be done, it may be effected by forcing exhaust (not live) steam through the coal in the stoker hopper.

Draft and Air Distribution

Under all load conditions and with all fuels, only a slight draft or negative pressure should be maintained in the furnace. This should average from 0.03 to 0.08 in. of water. With coke breeze and small sizes of anthracite it is particularly important to keep this draft as close to zero as possible. With coke breeze, having an exceptionally small amount of volatile matter, it is sometimes necessary to operate for a short period with a positive pressure of 0.01 to 0.02 in. of water in the furnace. This should be done, if ignition is being lost and the fire is not burning to within at least 18 in. of the feed-gate. If the fire starts to burn away from the feed-gate, the stoker should be slowed down or even stopped for a short time.

With forced-draft stokers, the air distribution in the various compartments must be governed by the kind of fuel used and the length of the fuel bed.

Burning bituminous coals with moderate moisture content does not present much difficulty. The amount of air in each compartment depends somewhat on the particular

make of stoker used, the number of compartments in the stoker, the ash content of the coal, and whether or not there is a rear arch and how far forward this arch extends. In general, in a five-compartment stoker, air distribution may be as shown in Fig. 6. If there are more or less compartments, air distribution should be governed proportionately. Bituminous coals with high moisture and lignites should have no air supplied to the first compartment and only a little to the second, as moisture must be driven off before ignition takes place. Air applied at this point chills the fuel and retards ignition. In other respects, air distribution should be the same as with other bituminous coals.

Air Distribution for Anthracite

In addition to the need of higher pressure to overcome the increased resistance, fine sizes of anthracite require different air distribution. These fuels are slower to ignite and the air pressure should be highest near the rear of the stoker. With No. 3 and No. 4 buckwheat, the rear arch should extend forward far enough to cover completely the last two zones and air pressure should not be sufficient to blow coal particles off the grate except under this arch where they can be deflected back onto the grate. Air distribution for this fuel, in general, is likewise shown in Fig. 6.

As with anthracite, coke breeze is slow to ignite, especially if wet, and the general shape of the air distribution curve is the same. Being much more porous, however, lower pressures may be used than with anthracite. The general shape of the curve is shown in Fig. 6.

It should be noted that with any kind of fuel and with all makes of traveling grate stokers, air pressures in the various compartments should be raised or lowered together, depending upon the combustion rate.

Stoker Expands While Banked

When taking a stoker off the line for banking, especially when the stoker has been operated at high rating, gradually decrease the air supply to the stoker by closing the air valves a little at a time. This will prevent damage to the stoker due to the large amount of heat absorbed by the arches and brickwork.

Fill the stoker hopper and shut off the fuel supply. Shut off the supply of forced draft air to the stoker, then close the air valves and the stack damper but do this only after the furnace is relatively cool, as the stoker will be damaged, if a large amount of heat is bottled up in the furnace. Raise the gate to a height of 12 in. and run the stoker at the highest speed until the hopper is empty. Leave no fuel in contact with the gate or the gate will burn out. Next slightly open the air valves to the compartment which is under the end of the green coal just run in and open the stack damper slightly. The fire will then burn slowly toward the front of the stoker. As the end of the fire comes over each zone, the air valves to that zone must be slightly opened and all other valves kept closed. When the fire reaches the front compartment, another hopper full of fuel must be run in exactly as described above.

After a banked period do not start the stoker until air has been blown through the grate for 4 or 5 min., or serious damage may result. The stoker grate surface during the banking period has become much hotter than when in normal operation, various parts have expanded and it must be cooled before starting.

Disposal of Ash and Siftings

Natural draft stokers have a greater percentage of air opening than forced draft and, as a result, a greater amount of unburned fuel will be in the upper pit. These siftings should be raked out on the floor and returned to the stoker hopper. With forced draft stokers, the siftings fall into the air compartments. If the grate surface is in good condition, the amount of siftings per day will be quite small but, if allowed to accumulate, this material will, in time, interfere with the air supply. Siftings should be removed at least once a month and inspection made at least once a week.

With either natural or forced draft, accumulation of ash in the lower pit may result in serious damage to the stoker. Cleaning should be at regular periods, the interval governed by the amount of fuel burned.

Underfeed Stokers

Stokers of this classification deliver coal into a retort by means of a ram. From the retort, the coal overflows to the side in the horizontal type or falls to the rear in the multiple-retort, gravity type. A typical example of the former type is shown in Fig. 7.

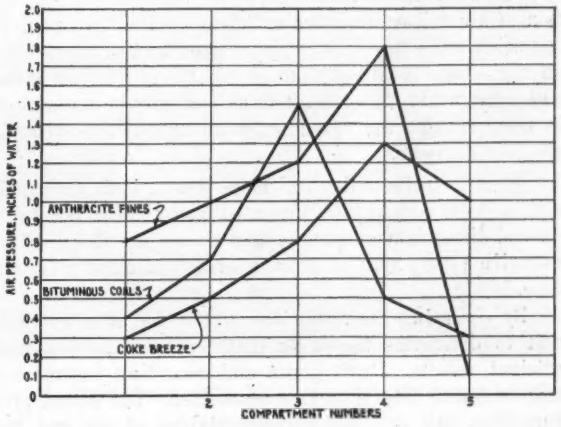


FIG. 6. THIS SHOWS AIR DISTRIBUTION FOR A 5-COMPARTMENT STOKER BURNING BITUMINOUS COAL, ANTHRACITE FINES, OR COKE BREEZE

Air is furnished to the fuel bed by means of forced draft which enters through tuyeres in the side of the retort. With the green fuel at the bottom of the retort, heat is supplied from the burning coal above for distilling the gas which ascends through the incandescent fuel bed and burns in the furnace above. As the fuel ascends in the retort, it becomes coked and then the fixed carbon is burned on the surface, the ash being pushed to each side or to the dump plate or clinker grinder at the rear, depending on the type. Representative examples of multiple-retort stokers are shown in Figs. 8 and 9.

Draft and Air Pressures

As the fuel bed thickness is usually from 18 to 24 in., forced draft is, of course, essential for effective operation. Air pressures in the main windbox vary from 2 to 6 in. of water, depending on the fuel and load conditions.

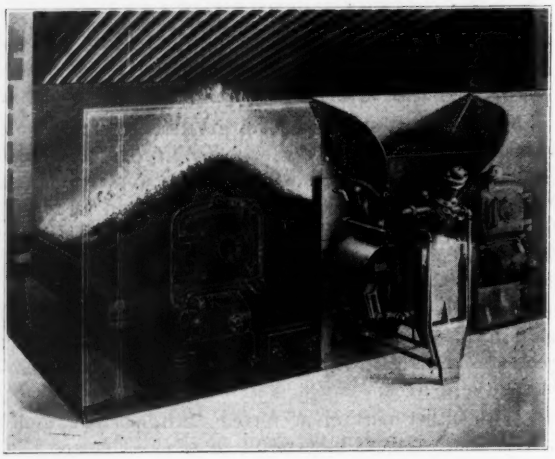


FIG. 7. HORIZONTAL TYPE OF SINGLE RETORT UNDERFEED STOKER

As with traveling grate operation, there should always be a slight suction in the furnace. Draft over the fire should be approximately 0.05 in. of water during normal operation. If the suction is over 0.25 in. of water, infiltration of air will cause losses sufficient to defeat economical operation. If a pressure is maintained in the furnace for an appreciable length of time, it is liable to ruin the stoker and brick work. The correct draft can only be maintained by manipulating the flue dampers in conjunction with the air-duct dampers.

When conditions demand more steam, both air supply and coal feed should be increased and vice-versa. Never control the steam output by the air supply alone. This will give a gas producer effect, wasting unburned gases and coke.

By observing the conditions of the fire, it is not difficult to determine the draft that will produce the most efficient results. Draft gages and recording instruments will be found helpful in this connection. The lowest pressure that will give the correct mixture of air and fuel should be used at all rates of combustion. Ordinarily 30 to 40 per cent excess air is required.

FIG. 8. REPRESENTATIVE EXAMPLE OF MULTIPLE RETORT UNDERFEED STOKER

As a rough method of checking the air supply, the flame at the top of the first pass should be observed. With the proper air supply, the flame will die out just about the time the gases leave the first pass, while, if too much air is supplied, the flame will die sooner or, if an insufficient quantity is supplied, the flame will be carried back through the other passes. Smoke from an underfeed stoker usually denotes a lack of air.

High Combustion Rates Are Possible

In general, it may be said that underfeed stokers will burn almost all kinds of solid fuels except fine anthracite and coke breeze. These small sizes, such as No. 2, No. 3 and No. 4 buckwheat, are better adapted to traveling grate stokers.

In underfeed operation, continual agitation of the fuel bed keeps it porous, even with coals that coke. Where quick steaming to meet sudden peak loads is desired, the thick fuel bed gives a fuel reserve which is a decided advantage. Eastern coals may be burned continuously at a rate of 60 lb. per sq. ft. per hr. while, for short periods, the combustion rates may be increased to 70 lb. With mid-western coals, however, the combustion rate should be lowered to 35 or 40 lb.

An advantage of underfeed stokers is the fact that no ignition arches are necessary. In some cases, this is quite a factor in furnace maintenance. With traveling grate operation, the fuel bed lies undisturbed and there is no piling up of coal at certain points as there may be in underfeed operation, if the feed of one retort happens to be greater than the others. For this reason and also due to the fact that the air is controlled by zones, there is less need for observation of the entire fuel bed than with underfeed stokers. With traveling grates, the fuel bed is usually observed through several small doors (about 5 by 7 in.) along the sides. With underfeed operation, the whole fuel bed usually is observed through large side doors (18 by 20 in.). The side door is the best point from which to observe the fuel bed because, if the portion of the fuel bed along the slope of the tuyeres is correctly maintained, the balance of the fire can hardly be otherwise than correct.

Starting the Fire

Fill the hopper with coal and feed about 3 or 4 hoppers-full into the furnace to cover the grates to a depth of about 4 in. If there is no power to operate the stoker, coal should be shoveled in by hand and evenly distributed over the grates. Put kindling and oily waste on top and near the front wall. Light the fire across the entire front so that it will get started evenly. At first, open the flue damper just enough to carry off the gas. In a few minutes the forced blast should be turned on gradually until the fuel is thoroughly ignited. If forced draft is not available at first, resort to natural draft by admitting air to the main duct, either by removing the front plate or at some other point in the duct. Once the fires are started, operation consists in adjusting the stoker engines, if such are used, to see that they are working properly.

Controlling the Fuel Feed

With all stokers of this type, fuel in the one or more retorts is pushed in by means of a main ram in each retort. After this, as combustion progresses, the gradual pushing down of the fuel is accomplished by auxiliary rams, located in the bottom of the retort, or by reciprocating motion of

the side bars: As a rule, eastern coals require less travel on the grates than the high-ash, high-volatile western coals.

When driving the stoker hard, it is usually desirable to give the fuel additional movement within the stoker as well as with the main rams, as too much green fuel may pile up in front. With multiple retorts, the same adjustment of the auxiliary movement should be given to the fuel in all retorts, unless there is a hole or else a piling up of the fuel bed at a certain point.

Care should be taken to see that the motion is not so excessive as to give too thin a fuel bed or to carry live coals down into the dump plates or clinker grinders. Remember that the lower end of the furnace is not intended for live coals but for ash. When starting a fire it is often well to cover the lower end of the stoker with ash to prevent burning of the exposed surface.

With practically every type of underfeed stoker, if the fuel is wet and with considerable fine material, the natural tendency is toward arching over the plunger and so preventing further feeding of fuel until this arch is broken. With some types, this arch is broken by the butterfly-valve action of a heavy wire loop cutting through the coal in the throat of the hopper. This device is attached to the main crank shaft which operates the feed rams. One type of stoker overcame the difficulty by having almost vertical sides to the hopper, eliminating the pronounced throat above the ram.

Fuel Bed Thickness

Over the tuyeres, a fuel bed of 24 in. is usually considered heavy, 18 in. is about normal and anything thinner than 16 in. is light. These thicknesses apply to a point about 2 ft. inside the front wall and apply more especially to large multiple-retort stokers. With single-retort stokers of the horizontal type, designed for lighter loads, the fuel bed thickness will be between 12 and 15 in.

As with traveling grate stokers, 1¼ in. screenings is the generally accepted size of fuel for underfeed stokers, although somewhat larger lumps may be used than with traveling grates.

To a certain extent, the same precautions as with traveling grates should be observed in the distribution of coal to the stoker hoppers. To avoid segregation of fuel particles the proper kind of spouts should be used.

For general operation, the proper and the incorrect outlines of the fuel bed for multiple-retort inclined stokers are shown in Fig. 10. Precautions should be taken by firemen to keep the entire fuel bed steadily uniform, since a heavy fire decreases both capacity and efficiency. This is especially true, if the rear end of the fuel bed is heavy while the front is light. Such a condition induces serious clinker trouble, as green fuel will fuse with the ash and clinker to the brick walls with consequent difficulty when dumping of ash is attempted. Fires should not be too light, however, as this generally introduces an excessive amount of air in the furnace with a consequent lowering of the efficiency.

Care should be taken in connection with relatively wide stokers to be sure that the fuel bed is of even thickness across the entire width. If one side is heavier than the other, feed should be stopped on this side and continued on the light side. This condition may also be corrected by adjusting the main dampers in the stoker windbox, if the windbox is divided longitudinally.

It seems to be the general consensus of opinion among operators, particularly where eastern bituminous is used, that tempering coal for use in underfeed stokers is unnecessary. Nevertheless, before any decided opinion is given, accurate investigation should be made of all conditions involved. In a few instances, conditions have occurred which led to the belief that uniform tempering would have given higher efficiency.

Ash Disposal

With multiple-retort stokers, ash and clinker should never be allowed to accumulate at the lower ends of the retorts or on the overfeed section. This will retard the flow of air to this section of the fuel bed and will result in a larger portion of the air being discharged through the top tuyeres, thereby causing rapid burning of the fuel next to the front wall.

With the dump plate stoker, there is a natural cycle between dumps for different grades of coal which can only be determined by observation; it is far better to dump

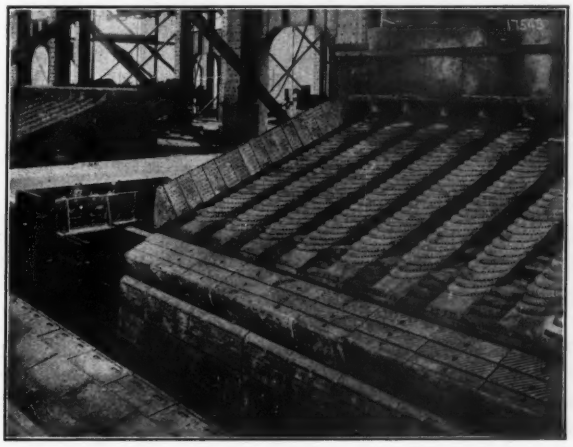


FIG. 9. REPRESENTATIVE EXAMPLE OF MULTIPLE RETORT UNDERFEED STOKER

too often than to wait too long. The only detrimental results will be that the combustible in the refuse may be somewhat higher and this can be controlled by proper adjustment of the extension-grate air damper.

When operating correctly and with best efficiency, the extension air damper can be kept closed at lower ratings, opening it only for 15 or 20 min. before dumping and for operation at maximum ratings.

In starting a fire on stokers equipped with rotary ash discharge, the crusher pit should first be filled with ashes up to the bottom of the extension grates. If this is not done, extreme care must be used to see that all fuel is burned out before being pushed into the crusher pit and a long interval of time will be required before normal fuel bed conditions can be established and high loads carried.

If the stoker is taken off for inspection or repairs, the crusher pit should be emptied and repairs made to this portion of the stoker first, if they are necessary, without removing the ash from the retort and tuyeres. Then the crusher aprons should be closed and the pit filled with the clinkers and the ash which were left in the retort and over the tuyeres. If this method is followed, the stoker can be fired up without delay.

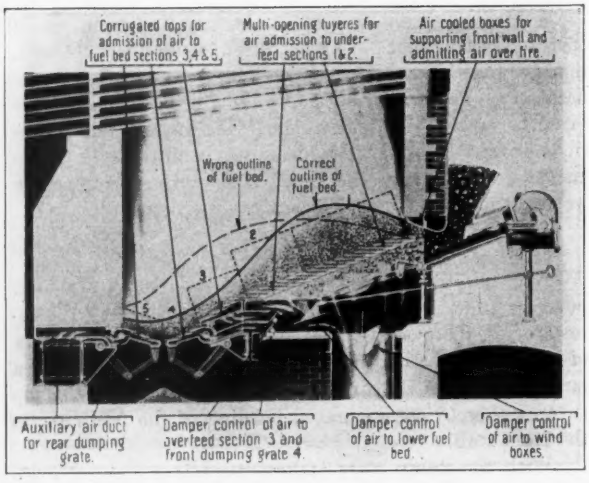

Corrugated tops for admission of air to fuel bed sections 3,4 & 5.
Multi-opening tuyeres for air admission to underfeed sections 1 & 2.
Air cooled boxes for supporting front wall and admitting air over fire.
Wrong outline of fuel bed.
Correct outline of fuel bed.
Auxiliary air duct for rear dumping grate.
Damper control of air to overfeed section 3 and front dumping grate 4.
Damper control of air to lower fuel bed.
Damper control of air to wind boxes.

FIG. 10. PROPER AND IMPROPER FUEL BED OUTLINES ARE HERE SHOWN

Setting Crusher Aprons

Crusher aprons should be set normally to within 2 or 3 in. of the crusher rolls. A greater distance will discharge ash more rapidly at some sections than others, cause uneven fires and affect the results. A shorter distance will prevent the proper discharge of clinker and cause unnecessary wear and loads on the crusher teeth.

Little necessity should be found for changing the position of the crusher aprons, unless the ash should not be feeding down over some particular apron section. If the ash does not feed down into the crusher pit fast enough, it is better to increase the speed of the crusher rolls than to change the position of all the crusher aprons.

With the horizontal type of underfeed stoker, the ash is worked out on side dump trays and then dumped in much the same manner as with dump trays at the rear. Since there is no flat overfeed section between the tuyere bars and the dump trays, as with most of the rear dump type, care must be exercised in dumping so that, as the trays are dumped, a large clinker which may extend over into the live fuel zone does not suddenly tip up and carry partially burned fuel with it into the ash pit.

Keep the side walls and bridge wall free from clinker by using a slice bar frequently, if low grade coals having high ash and a low fusion point of the ash are burned. Coals with a high ash content of 18 to 22 per cent and a fusion point of 2000 to 2200 deg. F., are unsuited to the horizontal type of underfeed stoker.

Banking the Fire

In banking the fire, shut off all air, close the blast damper and partly close the uptake damper, so that the draft is just sufficient to carry off the gases. Feed just enough coal to the boiler to make the fuel bed as thick as circumstances require. By occasionally feeding a small amount of coal, it is possible to maintain the bank over a long period of time.

Use little, if any, auxiliary motion when pushing in coal during the banking period; with fires banked, it is good practice to have a little movement of the auxiliary pushers once in a while, just enough to keep them loosened up.

When raising steam from a banked fire, run the stoker a few revolutions with maximum auxiliary movement. After the fuel bed is broken up, turn on the air gradually to the required amount. If the fuel bed is heavy, run the stoker with the hopper empty so as not to feed in any more fuel until after the auxiliary movement has broken up the bed and it has had a chance to burn down to normal thickness. If the fuel bed is too thin, it will require some time to get under full headway. With a proper bank, high ratings can be obtained in a few minutes.

Overfeed Stokers

Stokers of the overfeed type are divided into two general classes, depending on whether the coal is fed from the front or from the sides.

Inclined front-feed stokers received coal from a hopper extending across the entire front of the furnace, the discharge from the hopper being upon an inclined coking plate from which it is pushed by oscillating plates, or slides by gravity to a series of rocking or oscillating grate bars extending across the furnace. At the lower end of the grate are dumping plates which hold the unburned coke until combustion is completed and also the ash accumulation between times of cleaning the fire. In most installations an ignition arch is provided for the front part of the stoker, of either the suspended or sprung type, the suspended type being more common.

Coal fed upon the coking plate has the heat of the furnace reflected down upon it by the ignition arch, thus driving off the volatile matter and igniting the coke. The inclination of the grate is usually about 45 deg., which is sufficient, with the aid of the grate-bar movement, to cause the fuel to descend. At the same time, the working of the grate breaks up the cakes of coke, provides air spaces through the fuel bed and sifts the ash to the space below. By the time it reaches the dump plates, the fuel bed consists of coarse ash, clinker and some unburned coke.

Use of Low-Volatile Coking Coals

These stokers are adapted to low-volatile, coking bituminous coals such as found in the eastern states, which require agitation of the fuel bed and are not particularly

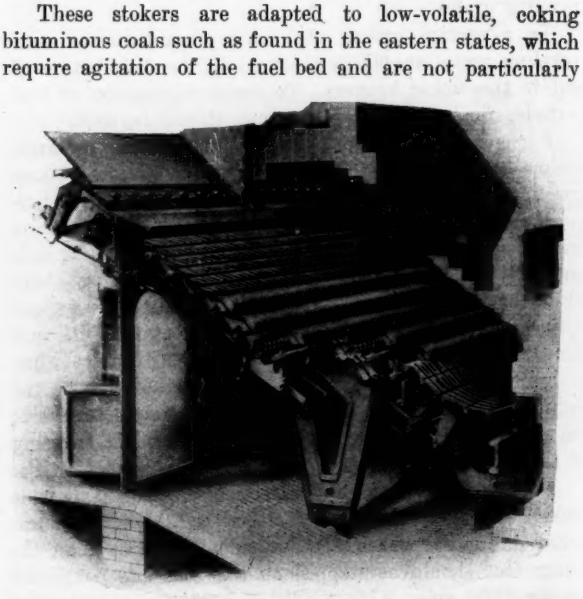


FIG. 11. THIS TYPICAL EXAMPLE OF A FRONT-OVERFEED STOKER HAS COAL FED BY A PUSHER PLATE

difficult to ignite. Forced draft has been used successfully with the inclined front-feed stoker but, if the fuel bed is more than 6 in. thick, the grates will not agitate it sufficiently for good combustion. When used with natural or induced draft, these stokers are unsuited to conditions where the load fluctuates rapidly from one extreme to the other. The maximum rate of combustion is about 35 lb. of coal per hr. per sq. ft. of grate surface, with draft over the fire at about 0.5 in. of water.

Side-feed stokers differ little in the principle of operation from the front-feed type. Use is made of two inclined grate surfaces, which face each other so as to form a furnace of V cross-section, the bars running parallel with the fuel bed. Coal hoppers are placed along the full length of each side of the furnace, which is always of the extended front type with an arch covering the entire space over the grates.

Adjusting of the Hopper Gate Opening Is Important

In operation of both of these types of over-feed stokers, the greatest difficulty is to adjust the hopper gate openings and the motion of the grate bars so that the proper combustion rate is secured, yet no holes develop in the fuel bed. These stokers are also likely to sift considerable fine unburned fuel through the grate during the early stages of combustion. With proper arrangement of the ash pit, these siftings are not lost, as they can be refired without much difficulty; but, if too much of the partly burned coal is put into the hopper at a time, furnace conditions are likely to be upset, resulting in a temporary reduction in efficiency.

Operation of Front Overfeed Type

In Fig. 11 is shown a view of a stoker of this type. Coal is fed from the stoker hopper by a pusher plate, which is mechanically operated, then passes over a dead plate which is given the same general slope as the grate hopper.

In starting the fire, the grate bars are first covered with wood, to prevent the coal from running from the hopper to the ash pit. The hopper full of coal is then fed in and ignited by throwing in a small amount of wood or oily waste, gradually feeding coal. In the absence of steam, this can be done by hand operation of the coal-feeding pusher, until the entire grate surface is covered with ignited fuel.

With this stoker, a fuel bed about 7 in. thick is maintained at the dead plate, tapering down to about 4 in. at the guards. This thickness varies, of course, with different coals and rate of combustion.

Draft regulation for the proper combustion rate should always be accomplished through adjustment of the boiler damper. Regulating the intensity of the fire by the use of the ash pit doors is not good practice, as it shuts off almost entirely the air supply through the fuel bed, with consequent smoke emission. The grate bars also become overheated and an increase of draft is produced through the boiler settings proper, causing considerable air to be drawn in through doors and cracks in the setting. Generally a differential gage indication of 1 to 1½ in. suction is satisfactory.

In the V type of over-feed stoker, coal is stored in side hoppers from which it feeds by gravity to the sloping grates. The fuel bed moves downward toward the center of the furnace, where the ash and clinkers are discharged through a clinker grinder which is mechanically operated, as are also the vibrating grates. The arch over the furnace may be of either the suspended type or the air-cooled, sprung type. A typical example of a stoker of this type is shown in Fig. 12.

Operating methods for this stoker are somewhat similar to those outlined for the front-feed type, although the thickness of the fire is somewhat less. A fuel bed 3 or 4 in. thick is recommended, although this varies depending on the coal, draft and load.

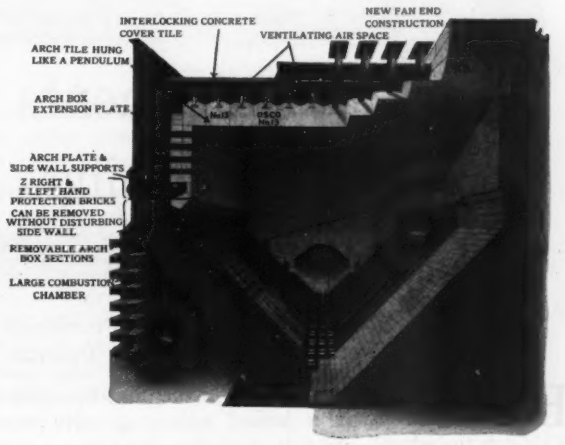

INTERLOCKING CONCRETE COVER TILE
VENTILATING AIR SPACE
NEW FAN END CONSTRUCTION
ARCH TILE HUNG LIKE A PENDULUM
ARCH BOX EXTENSION PLATE
ARCH PLATE & SIDE WALL SUPPORTS
2 RIGHT & 2 LEFT HAND PROTECTION BRICKS CAN BE REMOVED WITHOUT DISTURBING SIDE WALL
REMOVABLE ARCH BOX SECTIONS
LARGE COMBUSTION CHAMBER

FIG. 12. IN THE SIDE-OVERFEED STOKER FUEL COMES FROM THE SIDES TOWARD THE CENTER

To slice and break up the fires, in case of a sudden demand for steam, a slice bar is inserted through the capped roust holes on each side of the stoker. Push the slice bar in flat, along the grate and then draw it out on edge. Never roust the fire at the upper end of the grate.

Banking the Fire on an Overfeed Stoker

If it is desired to bank the fire, all the clinkers should be removed and the coal pulled to the front end of the grates. Fine coal is thrown through the fire door, covering the live coke; the doors on the front of the stoker are then closed and the breeching damper is nearly closed. To start up from a banked fire, the coke should be spread along the bottom of the grate and the grates covered with coal from the magazines.

General Pointers on Stoker Operation

If you have never had specific instruction in the operation of a certain make of stoker and there is no one around to give you accurate information, don't trust entirely to books but write to the manufacturer. Co-operate with him. He will be glad to help you.

Order your spare parts from him—don't try to make them yourself. Keep a reserve stock on hand at all times. All manufacturers have a Spare Parts Catalog. If you haven't one, send for it at once. Constant inspection and replacement of worn parts will greatly prolong the life of a stoker.

Stokers need lubrication as much as any high grade machine. Use only the kind of oil or grease recommended by the manufacturer.

Requirements for Burning Pulverized Fuel

ECONOMIC RESULTS FROM PULVERIZED FUEL. COAL-BURNING CONDITIONS MADE POSSIBLE PRESAGE RADICAL CHANGES IN PLANT DESIGN. BY H. D. SAVAGE*

BURNING of pulverized fuel, while to some extent revolutionary, was a logical and progressive step. Although the adoption of pulverized fuel firing was at first quite slow, the merits of this method of combustion have now been so thoroughly demonstrated by the numerous plants whose engineers had the ability and foresight to recognize its merits, that its progress in the last 2 yr. has been extremely rapid, particularly in the central station field where concentrated selling effort has been most aggressive. Industrial plants, where just as big opportunities for economies are offered, have been slower to adopt it, probably due to several erroneous impressions that seem to prevail in this field regarding requirements for pulverized fuel burning.

Frequently, the question is asked, "How small a boiler plant can justify pulverized fuel-firing?" This is purely a matter of economics, depending on the cost of coal and labor and the results obtainable with hand or stoker firing as against results obtainable with pulverized fuel firing.

Now that the unit method of firing is becoming more dependable, there would seem to be a considerable field for this development in industrial plants and that such a system can be justified in quite a small plant. In the New England States, for instance, where coal costs due to freight rates are and always will be high, great possibilities are presented for equipping the smaller plants. It is conceivable that, in the central states where coal is closely adjacent to the plants and costs are cheap, hand methods or an inexpensive type of stoker might produce just as good final economic results. But, as we go further west and get in the lignite fields, there is no question but that great possibilities are presented for unit systems of pulverized fuel firing in small plants and even greater possibilities for standard pulverized fuel systems in the larger stations because of ability to handle this fuel successfully at worthwhile ratings.

One reason that has been offered for not adopting pulverized fuel in industrial plants is that they have not the character of labor that is employed in central stations. This has always seemed rather far-fetched, for the reason that, with the exception of the engineering talent employed, the personnel of central stations varies but little from that of industrial plants. It would be difficult to set any hard and fast rule as an example for justification for equipping with pulverized fuel for, as stated before, it is purely a matter of economics and each case must be handled on its own merits.

While pulverized fuel firing was a forward step of great importance, the coincidental developments which it has produced warrant the statement that they will far overshadow in economic importance in the steam generating field the advantages of pulverized-fuel firing alone. These coincidental developments are, in the chronological order of their progress: Air Preheating; Water-Cooled Furnace Walls; Low Temperature Distillation.

Preheating of air is destined to play a far more important part in economical steam production than is realized at the present time and pulverized fuel firing combined with water-cooled furnaces has made it possible to take a fuller advantage of this valuable by-product recovery than has heretofore been possible, for the reason that, when employing preheated air, a limitation of the amount of preheat used was necessary or the increased upkeep on the furnace and equipment nullified the benefits derived from preheating.

Combination of pulverized-fuel firing, water-cooled furnace walls and air preheating has led to the development of a radical and startling steam generating unit, which unit will, undoubtedly, cause a great readjustment in the design of central stations. One of these units has been operating in a steel plant in England something over 4 mo., has 1977 sq. ft. of heating surface, has produced 70,000 lb. of steam an hour at an efficiency of 88 per

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cent with a draught loss through the complete unit of only 1.25 in. The total unit occupies a space of approximately 12 by 12 by 30 ft. This unit is now being offered commercially and a contemplation of what such a steam-generating unit means in the future trend of power plant design is interesting.

When the possibilities from such a unit are considered, in connection with the possibilities of firing semi-coke from a low-temperature distillation plant, the cumulative benefits are, probably, the last word in steam economy for years to come, considered from both an investment standpoint and operating results. It may be confidently stated that the development of pulverized fuel has been basically responsible for both these marvelous achievements for the low temperature distillation plant which we have in mind and which is being built on a commercial scale is based on pulverizing the fuel before carbonization, so that the resultant product from the retort is ready for boiler firing as it merges therefrom. This combination would seem to present, not only the last word in economical steam production, but a panacea for the greatest economic crime of the present generation, viz.: the burning of raw coal.

Operating Pulverized Fuel Equipment

SUGGESTIONS FOR OPERATING VARIOUS PIECES OF EQUIPMENT USED, CONTROL OF FURNACE FOR BEST RESULTS AND SAFETY PRECAUTIONS NECESSARY

IN THE OPERATION of a pulverized fuel fired power boiler by the general or storage system, the coal is usually crushed before it enters the green coal storage bin. From this bin it is fed either direct or by some sort of conveyor to the dryers. After passing from the dryer, the coal goes then to dry coal storage bins or direct to the pulverizers, the general arrangement being as shown in Fig. 1. From the pulverizers the pulverized coal is conveyed to smaller bunkers near the boilers; the feeders take the coal from these bunkers and feed it to the burners.

Coal from storage or direct from the railroad cars in which it arrives at the plant is usually dropped into a track hopper which feeds a short conveyor of some kind, either a belt conveyor or screw conveyor. This conveyor feeds a crusher which is usually located in a crusher room under the track or at the entrance end of the coal preparation plant. To make a satisfactory feed for the coal pulverizers, the crusher should pass a 1-in. or 1¼-in. ring for the present standard sizes of mills. Any standard type of crusher can be used.

Two types of dryers are available: the rotary, which has been standard for many years, and the vertical stationary type, of comparatively recent development. The indirect fired rotary dryer, illustrated in Fig. 2, consists of an axially inclined shell, rotated on its longitudinal axis and supported by suitable rollers. It is usually driven by a motor through gearing, as shown in Fig. 3. This shell is usually set at an inclination of from ½ to ⅝ in. to the foot. It is fitted with lifting shelves so arranged that the coal, while it is being dried, is lifted and dropped uniformly across the interior of the shell. Meanwhile, hot gases from the combustion chamber of the surrounding furnace are passing through the coal, attaining maximum contact with it. This shell is usually rotated at from 1 to 3 r.p.m. and the coal is gradually raised and dropped forward until it reaches the end of the dryer shell, where it is delivered into a hood. From here it is discharged as shown in Fig. 3, through a spout to an enclosed conveyor or elevator, which carries it to the dry storage bins above the pulverizers.

The vertical dryer, illustrated in Fig. 4, is a sectional box through which, in the usual arrangement, the coal flows by gravity on its way from the storage bin to the pulverizer. Hot gases under fan pressure or suction pass through the interstices in the body of the material and carry off the moisture. These gases are preferably taken from the boiler stack, in which case the term "waste-heat dryer" is usually used.

Flue gas enters the waste heat dryer at from 300 to 400 deg. F. and leaves at from 150 to 200 deg. One type of waste heat dryer takes gas at 250 deg. F. after it has left an economizer. The coal is usually heated to between

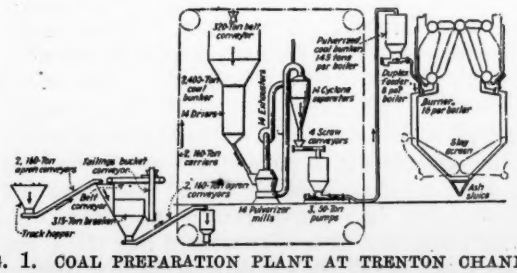


FIG. 1. COAL PREPARATION PLANT AT TRENTON CHANNEL

FIG. 2. COAL PASSING THROUGH INDIRECT ROTARY DRYER IS HEATED BY GASES AROUND AND THROUGH THE SHELL

FIG. 3. DISCHARGE END OF ROTARY DRYER SHOWING LIFTING TYPE MAGNETIC SEPARATOR IN DISCHARGE SPOUT

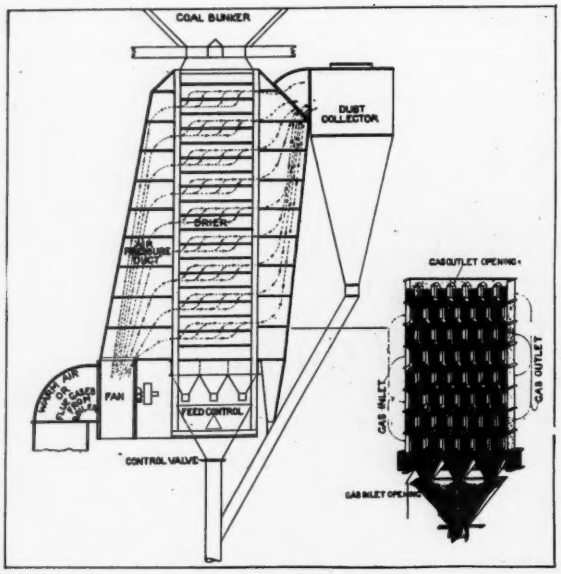


FIG. 4. FLUE GAS FROM BOILER DRIES COAL IN VERTICAL STATIONARY DRYER

125 and 175 deg. and passed to the pulverizers. These temperatures should, of course, be measured with suitable pyrometers installed in the equipment. About 3 lb. of gas per pound of coal would be a good figure for this type of dryer.

In installations having the preparation room at some distance from the boilers and in plants where economizers are used, a steam dryer, or a combination steam and waste heat dryer is often used. The steam dryer is of the same general design as the flue gas dryer, the coal passages being made of steam-heated grids. A small amount of air, about 1 lb. per pound of coal, is passed through the dryer to carry away the evaporated moisture.

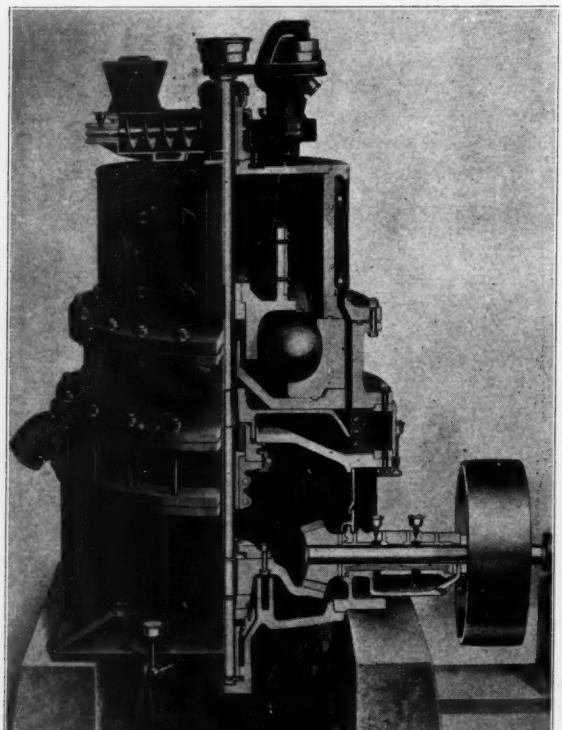


FIG. 5. SCREEN TYPE BALL AND RACE PULVERIZING MILL IS EITHER MOTOR OR BELT DRIVEN

Cyclone collectors are essential for removing the dust in the discharged gases from a rotary dryer and are desirable with a vertical dryer, particularly when the coal contains a considerable proportion of fines. In summer there may be times when the coal will be sufficiently dry before entering the dryer. In this case the coal is passed through the dryer, but the hot gases are eliminated.

Magnetic Separators Remove Tramp Metal

Coal discharging from the rotary dryer is received by an elevator and the spout leading from the dryer to the elevator may be equipped with a magnetic separator for the purpose of removing any tramp metal that may be in the coal. Sometimes the magnetic separator is installed ahead of instead of after the dryer. It is essential to keep tramp metal out of the pulverizers, as it increases the cost of repairs and causes delays. These magnetic separators are often of the lifting type, although in many installations, the pulley type is used. This is usually placed on one of the conveyor runs.

Conclusions from tests are that it does not seem necessary to dry the coal down to 1 per cent of moisture in order to get good boiler efficiency, as was formerly considered necessary. In fact, it seems that most of the eastern coals can be pulverized and burned with good results without drying. Actually, the net overall efficiency is about the same, whether the moisture is removed by any system of pre-drying, or evaporated from the coal in the furnace, provided the coal is dry enough to be handled satisfactorily by transport lines and feeders.

A test of a rotary dryer fired with pulverized coal, reducing the moisture content to 5 per cent, shows the following consumption of coal per ton of coal dried:

Lb. of Pulverized Coal Fired per Ton of Coal Dried	Moisture Content of Coal as Fed to Dryer
20	8 per cent
21	9 per cent
22.5	10 per cent
24	11 per cent
26	12 per cent
28	13 per cent
30	14 per cent
33	15 per cent

In the usual layout of the central type of preparation plant, using a rotary dryer, dried coal discharged from the dryer passes on a conveyor to a storage bin which feeds the pulverizer. It is recommended that this storage bin have a capacity of not less than two to four times the hourly capacity of the pulverizer. The bin should be provided with a hopper base and a suitable gate to permit shutting off the supply of coal when desired.

On account of the fact that the pulverizer discharges with the coal only a small amount of low pressure air, some sort of air chamber is usually provided for permitting the escape of this air, as in Fig. 1. It has been recommended that this chamber should have 1½ sq. ft. of cross-sectional area for each 33-in. or 42-in. mill, or 2 sq. ft. for each 57-in. mill discharging into the conveyor. This air chamber is vented to the inlet of a cyclone dust collector which serves to separate the air and dust. The air outlet

at the top of the dust collector should be arranged to discharge above the roof of the mill building. The dust outlet from the conical portion of the collector should be connected to the conveyor taking material from the mills.

Operation of Pulverizing Mills

Several types of pulverizers are available with varying capacities from ½ to 8 t. an hour, although recently, mills have been placed on the market with capacities up to 15, 20 and 25 t. an hour. Those in most common use are the ring-roller mill and the ball and race type mill, the latter employing either screens or air separation.

In the first type, rollers suspended on a spider from a vertical shaft, crush the coal against the inner surface of a grinding ring or bull ring. A fan draws the pulverized coal up into a separator at the top. This separator may be of either the single or double shell type, known as low side and high side mills, respectively. The pulverized coal must be exhausted from the machine, usually into a cyclone separator.

Figures 5 and 6 show typical examples of the ball and race type mill. In the screen type mill, Fig. 6, the dried coal to be pulverized is fed to the mill in a uniform and continuous stream from an overhead bin by means of an adjustable screw or cradle feeder, belt driven from the main shaft, except when it is directly attached to the bin,

SIZES, SPEEDS AND CAPACITIES OF ONE MAKE OF SCREEN TYPE MILL

	33 Inch		46 Inch		67 Inch	
	Belt Driven	Gear Driven	Belt Driven	Gear Driven	Belt Driven	Gear Driven
Floor Space	5'6" Dia.	5'6" x 8'3"	6'10" Dia.	6'2" x 11'8"	8'0" Dia.	8'0" x 14'10"
Height	9'11"	9'6"	11'4"	13'5"	11'7"	13'8½"
Speed of Driving Pulley (R.P.M.)	210	350 to 360	190	480 to 490	130	295
Size of Feed Through (Ring)	3/4"	3/4"	1"	1"	1¼"	1¼"
Output-Bituminous Coal (Tons per hr.)	2 to 2½	2 to 2½	5½ to 7	5½ to 7	8 to 10	8 to 10
Output-Anthracite Coal (Tons per hr.)	3/4 to 1½	3/4 to 1½	3 to 5	3 to 5	5 to 7	5 to 7
Fineness of Pulverized Material (Through 200 Mesh)	65 to 75 per cent	65 to 75 per cent	65 to 75 per cent	65 to 75 per cent	65 to 75 per cent	65 to 75 per cent
Power Bituminous Coal (Hp.)	30 to 35	30 to 35	85 to 90	90 to 100	100 to 125	110 to 125
Power Anthracite Coal (Hp.)	35 to 40	35 to 40	90 to 95	90 to 100	125 to 150	125 to 150

in which case it is motor-driven. The feed to the mill is regulated by two cone pulleys when the screw type feeder is used; and in the reciprocating type of feeder, an eccentric and link motion permits adjustment. In addition, the feed-hopper is provided with a slide by means of which the amount of material entering the feeder is regulated.

As the coal is discharged from the feeder, it falls into the pulverizing zone of the mill. Grinding is accomplished by the centrifugal and gravity pressure exerted by four unattached metal balls rolling against the hardened face of a stationary, horizontal, concave-shaped, grinding-ring.

The pulverized product, as rapidly as it is produced, is lifted from the grinding zone into the separating chamber by a current of air induced by the upper fan. The lower fan acts as an exhauster and draws the finely divided particles from the separating chamber through the protecting and finishing screen, which completely encircle this chamber, into the annular opening surrounding the mill, thence discharges the finished product through a spout conveniently located.

For pulverizing green or undried coal, containing such

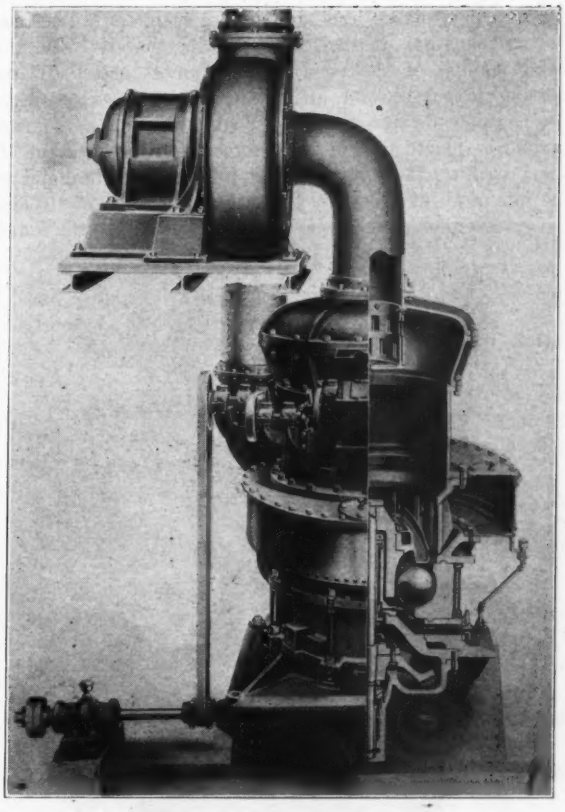


FIG. 6. AIR SEPARATION TYPE BALL AND RACE MILL

a large amount of free moisture that the screens in a screen type mill might clog, the ball and race mill of the air separator type shown in Fig. 6 can be obtained.

When pulverized coal was first employed in the power plant, it was considered necessary to pulverize the coal so that 95 per cent would pass through a 100-mesh screen and 85 per cent through a 200-mesh screen. It has been found that this is unnecessary and at the present time it is customary to pulverize so that between 65 and 75 per cent will pass through a 200-mesh screen, about 90 per cent through 100-mesh screen and not less than 99 per cent through 40-mesh screen.

Testing Fineness of Pulverized Coal

Fineness of pulverized coal can, of course, be determined by a screen test of samples taken from the mill during operation. A screen test, to be of value, must be made with accurate square mesh testing sieve. The screens

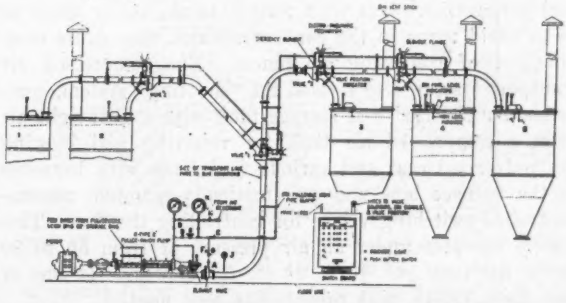


FIG. 7. ARRANGEMENT OF COAL PUMPING SYSTEM

are tightly stretched and mounted in seamless brass rims. Bottom pans are used to catch the fine material and the hand method of sieving is used in most cases. In reporting the results of an investigation of screen tests, the German Reich Coal Bureau suggests that a 25-gram sample be placed on the finest screen and screened for 10 min., striking the screen against the palm of the hand at the rate of about 125 times per min. After each 25 strokes, the screen should be given a quarter turn. It was found

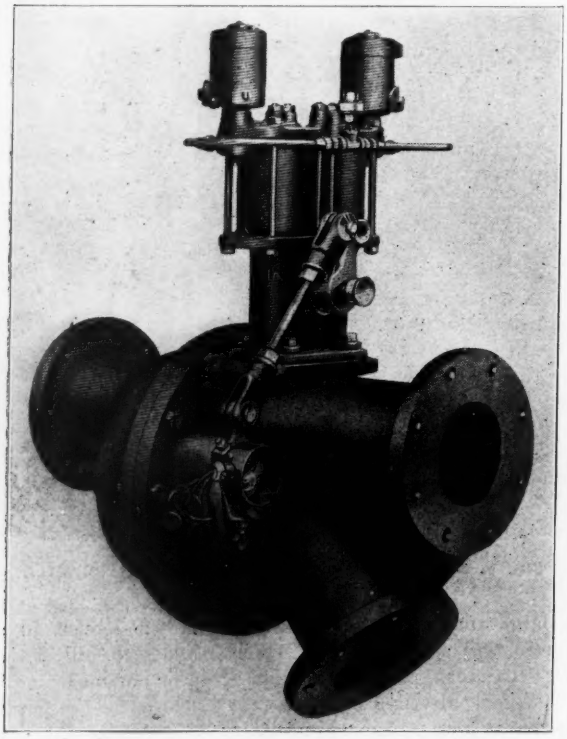


FIG. 8. THIS DISTRIBUTING VALVE IN COAL TRANSPORT LINE IS ELECTRO-PNEUMATICALLY CONTROLLED

that the bulk of the sample passed through the screen in about 5 min. The U. S. Bureau of Mines specifies a 50-gram sample, which would take longer to screen.

For the distribution of pulverized fuel from the cyclone collector to the furnace bins, several systems are employed. The most prominent of these are the screw conveyor system, the compressed air transport system and the pumping system. The first named type is used ordinarily for movement of comparatively large quantities of fuel on horizontal runs for comparatively short distances. When using this system, it is desirable to lay out the coal preparation plant with respect to the boiler house so as to avoid turns in the conveyor, which may cause complication of conveying equipment. The compressed air transport system, also termed the "shooting" system, comprises a pulverized coal storage tank with a dust-tight air gate, a compressed air tank for receiving and blowing the pulverized coal and various feed lines with branches to the furnace bins and pneumatically-operated, remote-controlled switching valves for controlling the flow. This system operates under an air pressure of from 50 to 80 lb. in the tank and 10 to 40 lb. for blowing. In one or two cases, 100-lb. tank presure has been used.

The use of compressed air and the use of the helical screw pump make it possible to locate the coal preparation plant in almost any convenient spot near the boiler house, in the case of an existing installation, and allow much flexibility in the design. In the latter method of transporting pulverized coal by pumping it, a valveless pump, Fig. 7, whose only moving element is a rotating helical screw delivers the coal direct to the transport line which is usually of black steel pipe from 2½ in. to 8 in. in diameter, depending on the amount of material to be pumped. Compressed air is admitted to the system at the point where the coal is discharged from the pump barrel into the pipe line. The compressed air serves to render the stream of pulverized coal in the pipe line sufficiently fluid to make it flow through the pipe, assisted, of course, by the propeller action given by the thrust of the helical screw. From the transport line, the coal may be discharged as in Fig. 7 through suitable regulating valves, Fig. 8, into bins or branches to other parts of the plant.

By means of a coal-weighing arrangement immediately above the pump, coal delivered to any particular bin can be weighed with considerable exactness. The total power requirements for this operation per ton of coal delivered varies between 1.3 and 1.8 hp. The air required for the pumping operation is approximately 6 cu. ft. of free air per cu. ft. of coal at a pressure varying between 15 and 30 lb. per sq. in., depending on the length of the line and the lift required.

A complete signaling system is used to indicate to the operator when the bin to which he is pumping has been filled and to permit him to operate diverting valves, such as that shown in Fig. 8, to change the flow to other bins which are in need of coal. The operation is often made automatic, in order to avoid any chance of overflow. An air-line by-passing the pump furnishes air for pneumatic valves and for clearing the line when desired.

In the central system of pulverized coal-burning, the coal is taken by one of the conveying systems just described to small storage bunkers in front of the boilers, from which the feeders take it to the burners.

In the central distributing system, the feeders in most common use are of the screw design, Fig. 9. Coal

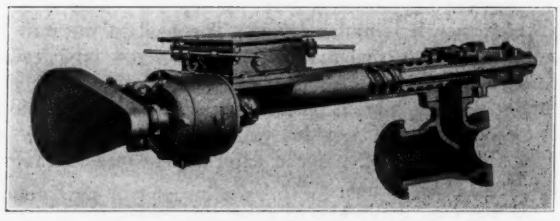


FIG. 9. UNIT TYPE PULVERIZED COAL FEEDER, DRIVEN BY VARIABLE SPEED MOTOR

enters the feeder through the large feeder-hopper, which is secured to the base of the storage bin as shown and the feeder is provided with slide gates to permit shutting off the supply of fuel. The feeder is conveniently driven by a variable speed motor of some kind, although variable speed mechanical transmissions are also used with groups of 2 to 10 feeders. Power required to operate one feeder varies between ½ hp. and 1½ hp. Two- and three-inch feeders at 110 r.p.m., with capacities of 400 and 1000 lb. per hr., respectively, require a ½-hp. motor, while a 6-in. feeder with a capacity of 6500 lb. of coal per hr. has

been found to require 1 hp. The variable speed motor can, of course, be controlled from the boiler control boards, which may be individual or centralized and this operation is, in many plants, connected with an automatic boiler control system.

The group type of feeder has now become standard equipment and can be provided in groups of from 2 to 10 feeders. These are all driven by a motor on one shaft, with variable speed mechanical drives for each feeder, the worms and pinions running in an oil bath.

Fuel burners, Figs. 10 and 11, are at the present time comparatively simple in construction, having developed from a plain pipe which was used for blowing the mixture into a furnace with or without secondary air. Generally speaking, types of burners used with feeders from a storage system provide for a small quantity of injection air at a velocity of about 100 or 150 ft. per sec., carrying the actual fuel to be introduced at the feeder; this injection air is about 10 per cent of that needed for combustion. This mixture is surrounded almost immediately after leaving the burner by a proportion of secondary air of about 20 to 30 per cent of that needed for total combustion, entering at b. The remaining secondary air at atmospheric pressure or at about 1-in. water pressure if taken from air heaters is supplied as at g, Fig. 12, through the furnace walls which are of the hollow wall type to allow this secondary air to be preheated.

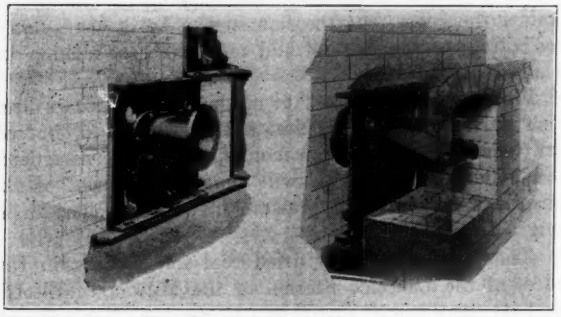


FIG. 10. HORIZONTAL TYPE PULVERIZED COAL BURNER

Starting operation of a pulverized fuel furnace is much the same as starting with oil. First, the damper is opened and one or two torches of oily waste attached to steel rods about 6 ft. long are held in front of the center burner openings. The torches should be burning brightly before any coal is turned on.

One or two burners are lighted at a time. When there are more than two burners the center burners are lighted first. The feeders are started at their lowest speed, about 25 to 30 r.p.m., at the rate of about 500 lb. of coal per feeder per hr. The air pressure on the feeder should be low—not over 5 or 6 in. of water. If the air pressure on the feeder is not too high, the coal will light readily and stay lighted. If the air pressure is too high, the flame may be blown out. It is better, therefore, to light the coal with very low air pressure and, after the coal starts to burn, to increase the air pressure. It is also better to put the lighted oily waste into the furnace first before the coal is turned on to avoid the possibility of filling the furnace with powdered coal before lighting it. If that should happen, an unpleasant puff of smoke might come up through the burners.

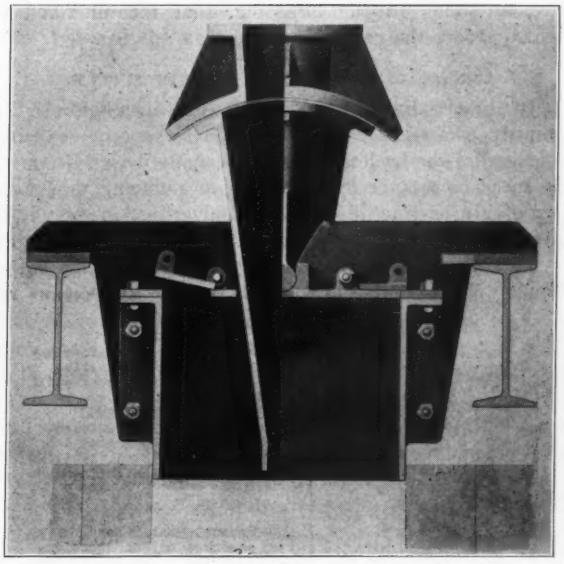


FIG. 11. VERTICAL TYPE BURNER

After the two central burners are well lighted, the burners on each side can be slowly turned on. These burners will ignite from the central burners which are already lighted. When all the burners have been lighted, the feeders can be gradually speeded up and the air pressure increased.

After the coal is ignited, the damper may be adjusted back to the proper setting, for say, 150 per cent of rating. Let it run this way for a few minutes until the boiler comes up to pressure, if it is not already at pressure. Be

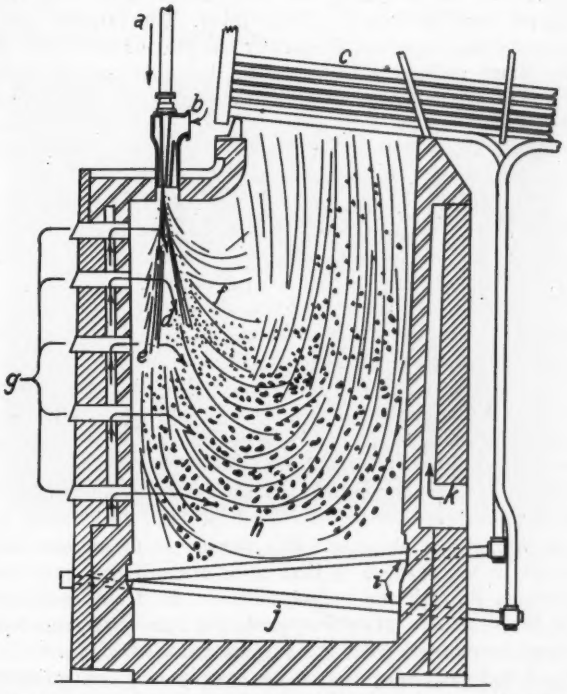


FIG. 12. METHOD OF FEEDING COAL AND AIR INTO FURNACE

a, coal and 10 per cent air; b, 20 per cent air; c, boiler; d, velocity 100 to 150 ft. per min.; e, velocity 10 to 15 ft.; f, fine coal particles; g, about 65 per cent air; h, coarse coal particles; i, water screen; j, ash; k, air to hollow walls.

sure, as stated in the foregoing, that the oil torch is lighted before the coal is turned on.

Controlling the Fuel and Air Supply

In practically all pulverized coal installations the quantity of fuel is controlled by increasing or reducing the speed of the feeders, which are usually driven by variable speed motors, or by increasing or reducing the quantity of air passing through the pulverizer, in case it is direct fired unit mill equipment.

In the operation of powdered coal furnaces, says Bureau of Mines Bulletin No. 237, the most important requirement for obtaining the best results is to keep the flames from striking the boiler tubes. The furnace operator should, therefore, frequently observe the condition of the flame under the boiler tubes. For this purpose each furnace might be provided with two large observation doors, one on each side, about 3 ft. below the boiler tubes and two small observation doors on each side of the furnace, about 1 ft. below the boiler tubes.

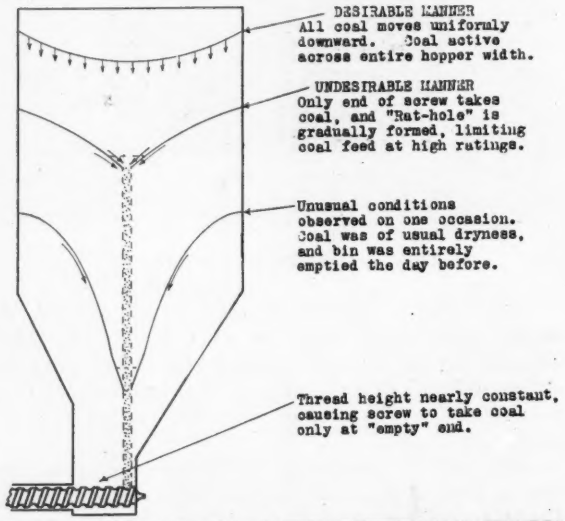

DESIRABLE MANNER
All coal moves uniformly downward. Coal active across entire hopper width.
UNDESIRABLE MANNER
Only end of screw takes coal, and "Rat-hole" is gradually formed, limiting coal feed at high ratings.
Unusual conditions observed on one occasion. Coal was of usual dryness, and bin was entirely emptied the day before.
Thread height nearly constant, causing screw to take coal only at "empty" end.

FIG. 13. CONDITIONS THAT CAUSED UNEVEN COAL FEEDING

The amount of primary air used for carrying the pulverized coal in the furnace in installations where storage supply bins are installed should be approximately 60 cu. ft. of air per pound of coal fed per minute.

Improper adjustment of the air supply may cause a general deficiency of the air supply in the furnace, so that coal cannot burn completely. Such a condition is indicated by the flames striking the tubes over the entire width of the furnace. The furnace temperature is usually high and molten ash may be seen trickling down the side walls and back wall. Under this condition accumulations of ash on the walls will soften and slide down to the bottom of the furnace and there will be dark gray smoke at the top of the chimney. The remedy is to increase the draft in the furnace so that more air will flow into the furnace through the hollow walls or the front openings. If the draft cannot be increased, the rate of feeding coal must be reduced until the furnace has cleared up.

Local deficiency in the air supply may bring about somewhat similar conditions. If the feeders on one side of the furnace are running faster than those on the other side, the flames may be seen to strike the tubes on the side where the feeders are running fast, although the flames may be clear and not nearly touch the tubes on the other side of the furnace.

When the rate of steaming must be increased, the speed of all the feeders should be increased in the same proportion, in order that all parts of the furnace may be made to burn equal amounts of coal. The draft must always be increased in greater proportion than the rate of feeding coal, because the rate of flow of air into the furnace varies as the square root of the draft. Therefore, if the rate of steaming must be doubled, the draft in the furnace must be quadrupled, in order that the coal and the air supply will be maintained in the proper ratio.

Preventing Flames from Striking Tubes

Flame may strike the tubes because the flames turn up before descending low enough into the furnace. The path of the coal is greatly shortened and the coal leaves the furnace before it is burned. This condition can be remedied by reducing the draft and increasing the air pressure on the feeders. Higher air pressure on the feeders will force the flame down into the furnace, making its path much longer, so that combustion is nearly completed before the flame reaches the tubes.

If flame strikes the tubes because the rate of combustion is too high, adjusting the drafts and air supply will not help; usually it can only be prevented by reducing the rate of feeding the coal. If the burners are equipped with steam jets, turning them on will reduce the smoke appreciably, and also reduce the striking of the flames against the tubes, but the flames may be driven against the bottom of the furnace and melt the ash, making its removal difficult.

When it is desired to shut down a boiler furnace fired with pulverized coal, the first thing to do is to shut off the feeder and then the fan motors, close all furnace doors and boiler damper. This will conserve the heat of the furnace walls and keep pressure up in the boiler for as long a time as possible.

Though using ideally dried coal for burning in furnaces at the Lakeside Station of the Milwaukee Electric Railway and Light Company, Milwaukee, Wis., considerable trouble was experienced some time ago in obtaining uniform coal feed across the 30 ft. width of each furnace. Below is a typical condition which existed consistently until corrected.

CO_2 across the furnace of No. 11 boiler:

West side	(⅓)	12 per cent
Middle	(⅓)	16.5 per cent
East side	(⅓)	16.5 per cent
Average		15 per cent

The offending coal feeder on the west side of the unit was thoroughly cleaned and inspected, without results, until the fundamental cause was determined. It was learned that pulverized fuel is of such nature that small vertical feed holes, reaching a dozen or more feet upward to the top of the coal surface in the bin, may be caused by localized withdrawal of coal in the bin hopper. The feeders in use up to the time, which were of a standard type, drew coal only at their "empty" end, Fig. 13, thus localizing the coal movement in the hopper bottom and caused the formation of a restricted vertical shaft, thus limiting coal feed. The troublesome feeders fed constant amounts of coal irrespective of feeder speed, leaving other feeders to take variations in delivery. At high ratings, in some special cases, secondary combustion was observed past

the first pass in the boiler. In the unit above referred to, the brick erosion on the east wall was greatest, while the west wall remained in exceptionally good condition. The trouble was satisfactorily corrected by tapering the feeder screw, causing it to gather coal progressively from across the entire hopper width. This is another illustration of the importance of keeping pulverized coal in motion.

Uneven Co_2 Detected by Temperature Variations

As an outgrowth of the preceding problem and of the continued feeling that development of feeders capable of accurately delivering equal amounts of coal will not be immediate, a method of detecting uneven CO_2 across the furnace width was developed, as reported in the Pulverized Fuel Report of the N.E.L.A. Prime Movers' Committee for 1925.

This method employs thermometric means of adjusting for equal CO_2 and is based upon the observed fact that the air supply across the width of a pulverized fuel furnace is nearly constant. Since the air flow is uniform, any difference in coal feed across the furnace width causes a difference in CO_2, and incidentally a marked difference in the temperature past the first bank of tubes in line with that high or low coal feed. This difference is the variation commonly known to exist with change of rating and, under the conditions at Lakeside, 1 per cent CO_2 difference in that part of the boiler is detected by approximately 40 deg. difference in temperature above the first pass. Thus, the operator has merely to keep five thermocouple temperature measurements together on a record chart to know that equal CO_2 exists across the entire furnace width. The method has been found to be a reliable and sensitive guide.

With low grade fuel, close furnace regulation must be maintained to prevent slagging. At the same time high furnace temperatures are necessary for best efficiency. The most important factors controlling slagging of side walls are proper cooling of walls and prevention of flame impingement with the resulting erosion. Control of wall temperature is limited by the air required for good combustion, a generous supply of air being needed to keep the side walls cool and to prevent the flowing of ash and refractories, while at the same time this large amount of air is usually an excess, which lowers CO_2 and boiler efficiency.

The use of water screens and the water cooled wall has become so fixed in the general firing scheme in this country that an empirical statement of the burning of a certain amount of coal per cubic foot of combustion space is frequently made. This is given as 1 to 1½ lb. of coal per cu. ft. per min., although efficiencies change only slightly in a properly designed furnace up to 2 lb.

Water screens are used in so many pulverized coal furnaces that, under proper operating conditions, the ash that drops through them does not fuse and can be easily handled by mechanical methods or by sluicing. It is estimated that from 25 to 50 per cent of the ash remains in the combustion chamber, 5 to 12 per cent is caught in the first pass, 25 to 35 per cent is caught at the base of the stack and from 12 to 25 per cent is lost through the stack. This stack emission is, of course, a fine, light powder and is apparently not deposited in any deleterious amounts near the stack. Operation of ash-handling equipment used with pulverized fuel furnaces will be discussed in more detail elsewhere in this issue.

It is the object of the unit pulverizer to combine in one machine all the equipment necessary to pulverize green coal and feed it to the burners. Figures 14, 15 and 16 show types of the unit pulverizer now on the market.

Operating and Production Costs

A summary of the information obtained from plants in operation at the present time, indicates that about 21 kw-hr. are required per ton of coal for unloading, conveying, crushing, pulverizing, transporting and feeding. This refers to the later installations using large mills. For plants using smaller mills this figure would be nearer 27 kw-hr. per ton.

Preparation and transportation costs including operation, maintenance and power, vary from 20 to 27c per ton, depending upon load factor, moisture content of coal, method of drying and labor rates, these figures applying to labor rates of about 70c per hour. Approximately 50 per cent of the above cost would cover operating labor and material, the balance representing maintenance and power. Fixer charges are not included in these rates.

Today, the modern pulverized coal preparation plant is perfectly safe when operated with any degree of intelligence. There is no danger in handling pulverized coal when proper precautions are taken and modern types of equipment installed. In any plant where the coal is prepared, however, a certain amount of attention should be given to keeping the plant clean and, as the equipment can be operated in a dustless manner, it requires but little attention to keep it in this condition constantly.

Special Safety Precautions

While there is no doubt that the risks involved in the operation of the pulverized fuel plant have been much exaggerated, and although the tendency towards greater simplicity in design and equipment have tended, and will undoubtedly tend still further, to minimize the risks of explosion and fire, it would be idle to suggest that all precautions are unnecessary.

FIG. 14. THIS UNIT PULVERIZER IS A BALL MILL, FINES BEING TAKEN OUT BY AIR SEPARATION

It may be well, therefore, to note the following suggestions, which particularly refer to indirect or central systems, and which were made by L. D. Tracey, Coal Mining Engineer of the Pittsburgh Experimental Station of the United States Bureau of Mines, as the basis for regulations for the safer operation of pulverized fuel plants:

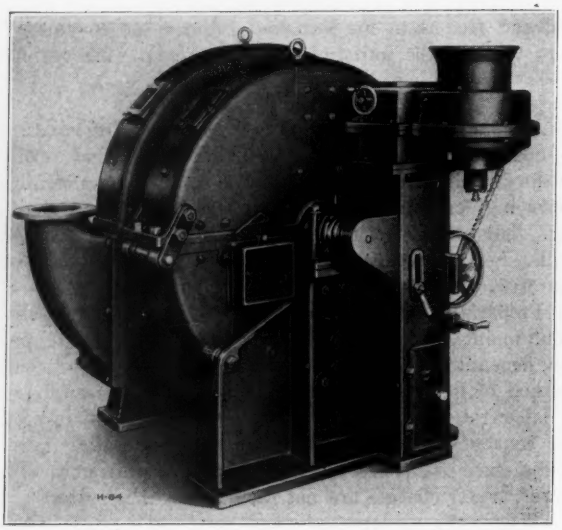


FIG. 15. HOT AIR IS SUPPLIED TO THIS DOUBLE EFFECT UNIT PULVERIZER TO DRY COAL WHILE IT IS PULVERIZED

Insist upon cleanliness and freedom from accumulations of dust, both in the pulverizing plant and in the buildings in which the pulverized coal is used as a fuel. Adequately ventilate and light all coal pulverizing plants and when practicable install some method of cleaning by a vacuum system. All open lights in and around the plant should be prohibited, and employes should not be allowed to smoke while in the building. This rule should also apply to superintendents and other officials who casually visit the plant. Special care should be taken not to overheat the coal in the dryer. The operation of the dryer should never be stopped while it contains a charge of coal.

Whenever a plant is to be shut down for a few days, all storage bins should, if possible, be emptied of coal. Where it is not possible to empty the bins, they should be thoroughly inspected for hot coal, before the plant is again put into operation. If a coal transport line becomes plugged up, the furnaces should be immediately cut off, and the secondary air supply stopped. After it has been cleaned, it is essential that no smouldering particles of coal be left in the line. Before starting the fan, a thorough examination should be made. Transport lines should be blown clear of coal when shutting down at the end of the day's work. All conveyors and elevators should be tightly enclosed and never opened while running. Stop the machinery and allow the dust to settle before opening. Never open a coal line, compressed air tank, or storage bin in the vicinity of a flame or open light. Enclose all electric wires and cables in conduit as far as possible All switches should be placed outside the plant or in dust-proof casings. Non-sparking motor, or motors in dust-proof housings, should be used. Guard against sparks from static electricity in all rapidly moving machinery by having it thoroughly grounded. All electric light bulbs should be kept free from an accumulation of dust and all portable bulbs protected by heavy wire guards. Care should be taken to prevent arcing from loose socket connections or imperfectly insulated cords. Stop all leaks in pulverized coal transport lines or storage bins, as you would in a gas line.

Both coke and lignite can be pulverized and burned satisfactorily. In regard to coke, however, it might be well to point out that it is much more abrasive than the hardest of hard anthracite coal. The question of its use depends, however, upon the quality of the coke and the cost of the fuel operation as a whole. The wear and tear or maintenance is practically double that required for soft coal. Furthermore, the capacity of the individual pulverizers is reduced from 30 to 50 per cent, depending upon the hardness of the coke braize or coke that is used.

Lignite makes a satisfactory fuel for burning in pulverized form. It usually has a high percentage of both free or extraneous and combined or inherent moisture. Just what treatment the coal needs for any particular installation depends upon the quality of the lignite available, the quantity proposed to be used and the prices of other competing coals delivered at the same location.

As a result of some tests, using pulverized Texas lignite at the Island Station of the St. Paul Gas Light Co., the following conclusions were reached: That the temperature of the gas leaving the dryers and the temperature of the coal leaving the dryers should be above 125 deg. F. to avoid condensation of the moisture; that the feeder screws to the burners should be larger than those installed for coal, such as Youghiogheny screenings or Elkhorn screenings; that the boiler tubes should be blown often; that the bottom rows of tubes of the boiler should be widely spaced so that the deposit on the tubes will break off by its own weight before the gas passages become stopped; that the furnace volume should be larger so that the molten ash will not be carried up into the boiler to condense and solidify upon the tubes, and yet allow a high CO_2 to be carried; that the moisture carried out in the flue gas is high, and hence the corrosive action in the boiler, breeching and stack is likely to be more noticeable.

In Germany, raw lignite has been pulverized at the rate of 450 t. per day and used in a steel works there. Lignite is crushed and dried to reduce the moisture content from 60 per cent to 15 per cent. After pulverizing, it is transported to various furnaces by compressed air. The coal as fired contains 12 to 18 per cent moisture, 15 per cent or more of volatiles and is usually of a fineness such that 15 to 30 per cent remains on a screen of 4900-mesh per sq. cm. The ash content varies from 5 to 9 per cent, although lignite with an ash content as high as 37 per cent has been burned successfully.

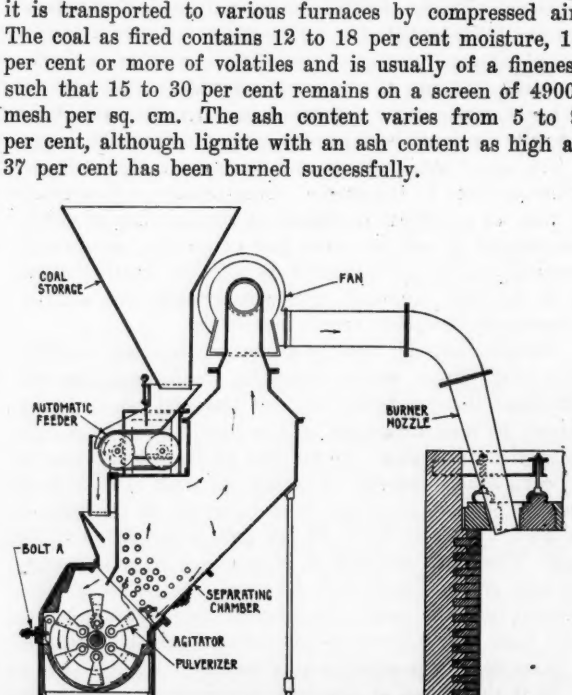
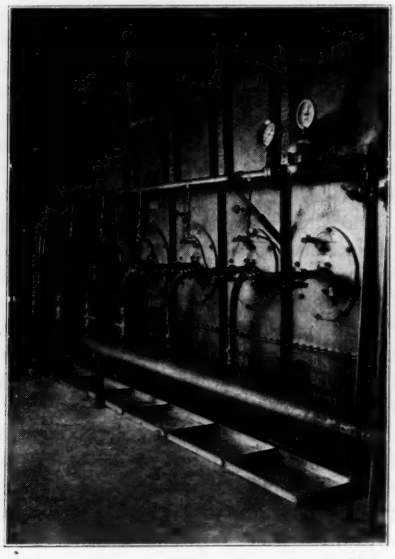
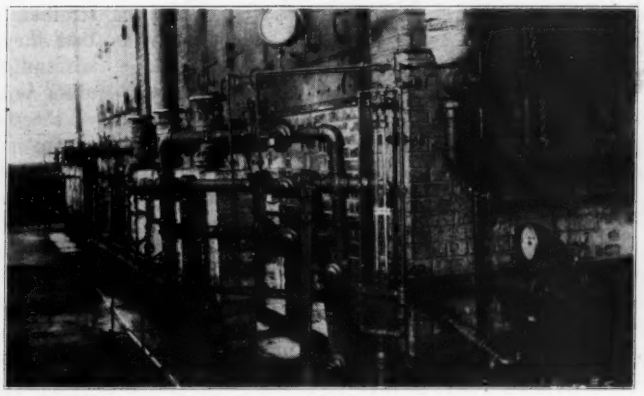


FIG. 16. UNIT PULVERIZER USING AIR SEPARATION





Burning Fuel Oil

A Discussion of the More Important Factors Governing the Successful Burning of Fuel Oil. By Frank A. Rothwell

AMONG THE various requirements for the successful burning of fuel oil, the two most important are—thorough atomization and the correct amount and application of air for combustion. The design of the furnace tends to augment these requirements, but with atomization and air supply correctly taken care of, fuel oil may be burned with a considerable degree of satisfaction in almost any furnace.

Furnace Should Be Designed Carefully

With reference to the longevity of the refractories, when using oil fuel, the design of the furnace plays a most important part. The general arrangement of the furnace for fuel oil is quite simple and embodies none of the complication of arches, such as is attendant with coal. The contour of the oil-fired furnace is nothing more than a square or rectangular room with the lower rows of tubes forming the roof. It is unnecessary to supply any form of impingement wall or arches to support combustion as in the burning of fuel oil with low excess air, the furnace walls are amply heated to support the necessary combustion. By the employment of impingement walls, localization of heat often occurs, causing overheating and the consequent blistering and failure of tubes.

Atomized fuel oil should be burned in suspension as a gas and the gas should not impinge upon the walls or floors, since rapid deterioration of the brickwork is the result of such impingement.

Three important items enter into the design of the furnace for fuel oil; these are—volume, air supply and atomizer spacing. Sufficient volume is necessary for the time element in the burning of the atomized fuel; correct air supply and introduction for the intimate mixing of the atomized fuel oil and air; correct spacing of the atomizers to eliminate the danger from excessive and undue brickwork failure.

The principal features of efficient operation may be grouped under several distinct headings. The most important factor of furnace efficiency is the supplying of the correct amount of excess air in order to complete the desired combustion. Inasmuch as it is not practical to supply the theoretical amount of air to produce perfect combustion, it is necessary to supply sufficient excess air to complete combustion. If great care is not exercised, percentages of excess air as high as 150 and 200 are common. This excess air is undoubtedly the most common cause of low furnace efficiency. Generally speaking, combustion is good, if the excess air is below 40 per cent and excellent if below 15 per cent. With an excess air of 15 per cent to 40 per cent, a CO_2 content of 11 per cent to 13 per cent may be obtained. From 8 per cent excess air, about as low as practical, to 15 per cent, a CO_2 content of 13 per cent to 15 per cent may be obtained.

A simple formula for the computation of excess air from the gas analysis is: $O \div (264\,N - O)$, in which the indicated symbols are the percentages, by volume, of the oxygen and nitrogen in the gas analysis.

Since excess air is the most common cause of low furnace efficiency, by all means the plant should possess a hand Orsat. The intelligent use of the Orsat is a most positive aid in obtaining maximum efficiency. It must be remembered that, unless properly handled, results may be obtained that are quite misleading; hence, only a competent person should be allowed to handle the Orsat.

It is not good practice to allow the firemen to regulate their fires from the appearance of the gases emitted from the stack. When more than one boiler is connected to the stack, such observation is sometimes misleading. If four boilers have a common outlet for their gases, one furnace may be causing all of the haze effect at the stack, while the other three may be perfectly clear and have considerable excess air. The most efficient point of observation

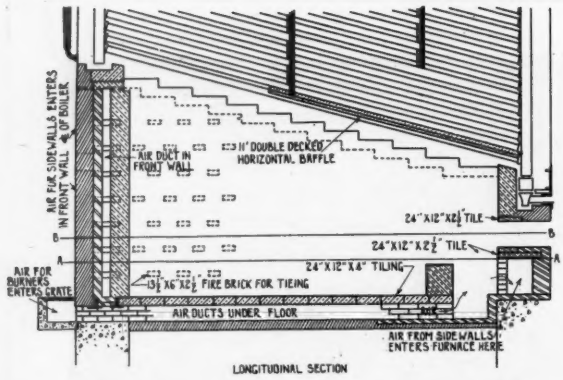

AIR FOR SIDEWALLS ENTERS IN FRONT WALL OF BOILER
AIR DUCT IN FRONT WALL
3 H' DOUBLE DECKED HORIZONTAL BAFFLE
24"X12"X2½" TILE
24"X12"X2½" TILE
24"X12"X4" TILING
13½"X6"X2½" FIRE BRICK FOR TIEING
AIR FOR BURNERS ENTERS GRATE
AIR DUCTS UNDER FLOOR
AIR FROM SIDE WALLS ENTERS FURNACE HERE
LONGITUDINAL SECTION

FIG. 1. ELEVATION OF FURNACE SHOWING DEFLECTION WALL

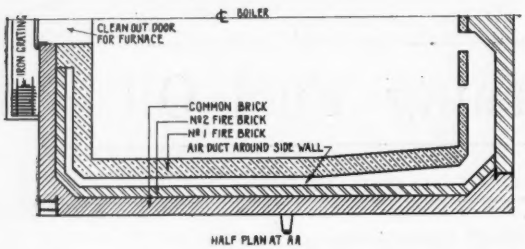


FIG. 2. HALF PLAN AT A-A IN FIG. 1

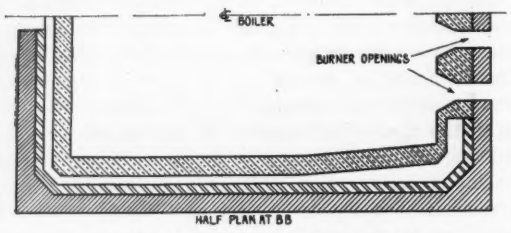


FIG. 3. HALF PLAN AT B-B IN FIG. 1

is at the bottom of the first pass. With the furnace full of flame and the flame melting out just before it enters the bottom rows of tubes, the excess air may be considered at a minimum.

Since CO_2 is of the same color as air, it is inadvisable to try to have the furnace full of completely burned gases. With such operation it is easy to have considerable excess air when we think we have CO_2. Flame consists of particles of combustible in the process of combustion and, if the air for combustion is supplied so as to consume this flame just at the point where it starts to enter the first pass, there is little danger of excess air.

Watch the Atomizers

Condition of atomizers is important in order to obtain the maximum furnace efficiency. Four distinct essentials for the proper operation of the atomizers are—fineness of atomization, proper straining of the fuel oil, proper heating to reduce the internal friction of the fuel and cleanliness of the atomizer tips. The first of these essentials is wholly dependent upon the other three, assuming, of course, that the atomizer is properly designed.

Thorough straining of the fuel oil before it reaches the atomizers is very essential. The fuel oil may contain silt or fine gritty substance which may tend to clog and injure the atomizer tips. Strainers should not be too coarse—a 26 or 28 mesh being best suited for this service. The strainers should be placed on the suction of the pumps so that they may also protect the working parts from the silt and gritty matter. The strainers should be cleaned as often as their condition demands, since the accumulation on the strainers resists the flow of the oil to the suction of the pumps. The area of the strainer screen should never be less than three times the area of the fuel line in which they are installed. The excess area allows of a large amount of accumulation without danger of adding to the normal line resistance of the suction of the pump.

Insufficient air, alone, does not cause the presence of smoke. If silt and foreign matter are not strained from the fuel oil, smoke will be formed due to poor atomization.

Fuel oil is heated before introducing it into the furnace for one particular reason, namely, to reduce its viscosity or internal friction. Some fuel oils are so low in viscosity that they do not require heating. Heating of the fuel assists operation materially in two ways. It makes pumping easier and it helps considerably the atomization of the fuel. For the general run of fuels it is unnecessary to heat them above 190 deg. F., as their viscosity is not reduced materially by heating above this temperature. The majority of commercial fuel oils do not possess sufficient "light end" hydrocarbons to be dangerously volatile at this temperature and too low temperature of the fuel oil will cause smoke because of improper atomization.

In the process of operation, coke forms on the atomizer tip and unless this is removed it will cause a streaky appearance of the atomized oil as it leaves the atomizer tip. It is also the cause of smoke. The intervals of cleaning the burner tips will vary with fuel quality, method of application and general operating conditions and no general rules can be laid down. In order to facilitate changing the atomizers, the unions that connect the atomizer to the steam and fuel lines should be fitted with wings, so as not to require a wrench for changing. The simpler the operation of a piece of equipment is made, the more effective will be its use in the hands of the operators.

When increasing or decreasing the capacity of a steam atomizing burner, it must be remembered that the atomizing steam should also be increased or decreased. It is poor operation to inject more steam into the furnace than is absolutely necessary.

With all of the furnace equipment in shipshape condition, the regulation of the damper in the breeching is the most important factor in obtaining high furnace efficiency. The damper position should be changed with every change in firing rate, however slight. Correct damper manipulation cannot be emphasized too strongly. Fuel oil may be burned efficiently with a pressure in the furnace. Even at high ratings the furnace draft need not be in excess of 0.05 in. of water. The correctly designed furnace, with the boiler efficiently baffled, can maintain combustion for 200 per cent rating with only a draft loss of 0.20 in. through the boiler.

Introduction of Air for Combustion

Air distribution for the fuel oil furnace is accomplished in three ways. Checkerwork in the furnace floor, deflection wall, Fig. 1, for introducing the air at one definite point under the atomizer tip and by air registers which introduce the air around the atomizer tip. The

checkerwork is fast losing favor since the floor ports fill with slag, causing a severe reduction in the capacity of the boiler. At its best the checkerwork method has a very limited overload capacity. The deflection wall and the air register each has its distinct advantages. The deflection wall is admirably adapted to the flat flame atomizers. The air registers are adaptable to the cone type atomizer and have their advantage in the fact that they can be used in banks the same as mechanical atomizers; that is, as many of the atomizers can be placed in the wall of the furnace as the area of the wall permits. Heretofore, with steam atomizers, it was necessary to place the atomizers side by side. With the air registers it is now possible to raise the boiler to get additional combustion space and place the atomizers in two rows, one above the other.

Air introduction and distribution are factors of the first magnitude in the successful burning of fuel oil. As stated, oil fuel should be burned with 8 to 15 per cent excess air. The more thorough the mixing of the air for combustion and the atomized fuel, the less the excess air required for the complete oxidation of the fuel. Fuel oil, at any rate of combustion, has a definite affinity for oxygen and the air should be introduced at the right velocity to satisfy this affinity. The air should be introduced into the furnace easily, which may be accomplished by controlling the air supply with the damper alone. High velocity has a tendency to supply more air than needed unless carefully watched.

Relative to the matter of obtaining proper air distribution, air cooled walls can be employed to a definite advantage. The life of the furnace lining is prolonged to a marked degree. Figure 1 shows a furnace which is entirely surrounded by air ducts. The air from the furnace walls is used in conjunction with the air from the main duct, under the furnace floor, for combustion. A furnace of this kind, supplying heat to the boiler for 185 to 250 per cent of rating, has completed 13,000 hr. of intermittent operation without a furnace repair. The fuel is burned with 10 per cent excess air, using flat flame steam atomizers.

Preheated air, from the walls and floors, assists materially in obtaining complete and rapid oxidation of the fuel. It enables the atomized fuel to be burned more completely in suspension. Cold air cools the atomized fuel below its combustion temperature and delays its complete oxidation. Cold air has practically the same effect as cold oil. Tests of boilers with and without preheated air show that, with the air preheated, the overall efficiency is greater, draft loss less, furnace temperature higher and the temperature drop through the boiler higher. Preheated air is most desirable with oil fuel.

Arrangement of Pumps and Piping

Pumps, for the delivery of the fuel to the atomizers, should always be supplied in duplicate, to insure a supply of oil to the atomizers in case of a breakdown. It is good operation to run the pumps intermittently. The best type of pump to use is the screw, which has its advantage in the fact that it delivers a steady pressure to the atomizers without the use of air tanks. With a reciprocating pump, most largely used, it is necessary to nstall an air tank in the discharge line to minimize the pulsations caused by the stroke of the piston. The reciprocating pump is by far the most common in use and in Fig. 5 is shown a diagram of a Pulsometer that may be installed in the discharge line to eliminate the pump pulsations.

Steady pressure of the fuel oil is desirable, inasmuch as the spasmodic introduction of the oil into the furnace has somewhat the same effect as not keeping the fuel bed on a stoker of a uniform thickness. Excess air and incomplete combustion are the results.

Piping from the pumps to the atomizers should be as direct as possible, in order to eliminate excess pressures on the fuel line and excessive pressure drop from the pumps to the more distant atomizers. The pumps should be situated as close to the supply tank as is practical in order to reduce to minimum the friction of the suction head.

With steam atomizers pressures do not enter into the problem of atomizing the fuel oil. Only sufficient pressure is required to deliver the amount of oil necessary for the desired capacity of the boilers. Pressures of this class range between 25 to 80 lb. With mechanical atomizers, pressure is the main medium by which atomization is accomplished and service pressures from 100 to 300 lb. are employed.

With constant viscosity, the fuel pressure remains the same with all grades of fuel oil, since the internal friction of the oil is the same. Higher pressures than those actually needed to deliver the required quantity of fuel oil, result

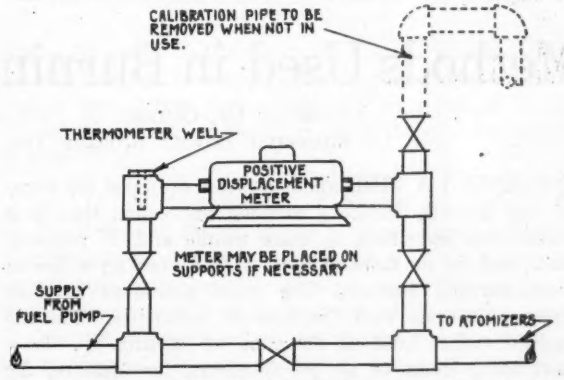

CALIBRATION PIPE TO BE REMOVED WHEN NOT IN USE.
THERMOMETER WELL
POSITIVE DISPLACEMENT METER
METER MAY BE PLACED ON SUPPORTS IF NECESSARY
SUPPLY FROM FUEL PUMP
TO ATOMIZERS

FIG. 4. METER ARRANGEMENT FOR CALIBRATION WITHOUT REMOVING FROM FUEL LINE

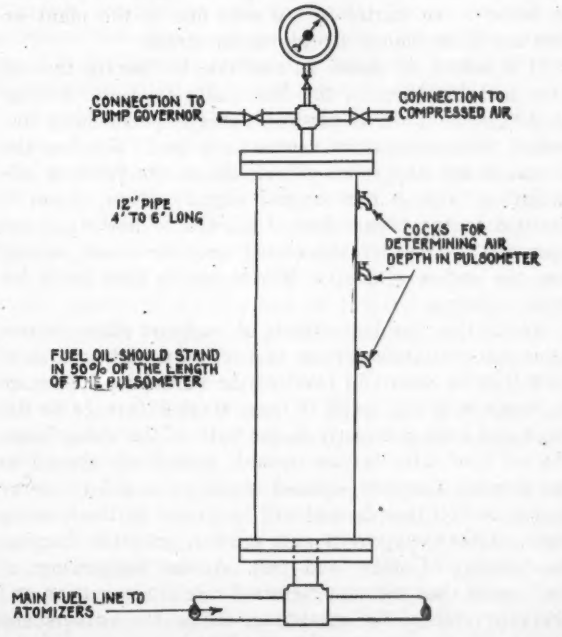

CONNECTION TO PUMP GOVERNOR
CONNECTION TO COMPRESSED AIR
12" PIPE 4' TO 6' LONG
COCKS FOR DETERMINING AIR DEPTH IN PULSOMETER
FUEL OIL SHOULD STAND IN 50% OF THE LENGTH OF THE PULSOMETER
MAIN FUEL LINE TO ATOMIZERS

FIG. 5. PULSOMETER

in increased steam consumption of the pump and undue strain on the fuel line.

If it is desirable to install a meter for measuring the fuel supplied to the furnace, it should be placed in the fuel line as it leaves the pump. Provision for the calibration of the meter is made so that it may be calibrated without removal from the line, Fig. 4 showing a diagram of a meter installation in which this provision is made. A thermometer well is inserted into the line entering the meter. The meter should be of reliable make, preferably of the positive displacement type, since a meter of this kind permits accurate adjustment.

Furnace Volume Needed

Volume of the fuel oil furnace should be sufficient to allow free burning of the fuel at a determined rate of combustion. The furnace and location of the atomizers should be such that the gases from combustion increase in volume with the increase in cross-sectional area of the furnace, as such an arrangement does not crowd the expansion of the gases.

Combustion space for the fuel-oil-fired furnace is spoken of in terms of cubic feet of combustion space per developed boiler horsepower. With mechanical atomizers, efficiencies of 81 per cent have been obtained at a rating of 300 per cent, the furnace ratio being 1.45 cu. ft. per rated b.hp. Although high efficiencies may be obtained with a furnace ratio of such small dimensions, the brickwork deterioration is alarming. A recent installation has 3.96 cu. ft. per rated b.hp., a rating of 350 per cent to be developed. The boilers are rated at 2000 b.hp., nine mechanical atomizers being used. The furnace shown in Fig. 1 has 1800 cu. ft. of combustion space for service under a 600 b.hp. boiler. Ratings of 265 per cent have been obtained easily. Flat flame, steam atomizers are used.

Considerable experience has proved that a furnace volume ratio of 1 cu. ft. per developed b.hp. is good for both steam and mechanical atomizers. Due to the intense heat developed by the mechanical atomizers, such volume is most desirable in order to forestall refractory failure. With the steam atomizers, excessive temperatures are not reached but sufficient volume is necessary to accommodate the volume of steam that is used by the atomizers..

In the design of the furnace, correct air arrangement cannot be emphasized too greatly. Bring the air to the tip of the atomizer as directly as possible and eliminate undue friction in the air ducts. This is especially essential with natural draft.

Methods Used in Burning Oil Fuel Under Boilers

Starting Up, Control of Fuel and Air, Checks on Performance, Shutting Down. Storage and Handling, Special Precautions

STARTING A FIRE under a boiler equipped for burning fuel oil, despite a common impression that it is a hazardous operation, is quite simple and, if properly done, need be no more dangerous than starting a fire in a coal-burning furnace. The exact procedure involved varies, of course, with the type of installation and the conditions that exist at the time of starting up. In a plant using steam or air jet atomizers, for instance, the procedure is slightly different from that in a plant using mechanical atomizers. It will also be different whether the boiler to be started is the only one in the plant or there are other boilers already under steam.

If a source of steam is available to operate the oil pump and the burners, the first thing to do is to open the damper as wide as possible. This is particularly important where mechanical burners are used. Keeping the oil and steam stop valves closed, the needle valve or oil-regulating valve is next opened slightly. Now, steam is admitted to the burner and is allowed to flow until the pipes and the burner are heated and the steam issuing from the orifice seems dry. The burner is then ready for actual lighting.

To do this, fashion a torch of waste or other inflammable material and attach it to a rod of such length as to allow it to be placed in front of the burner tip. Saturate the waste with oil, ignite it from another furnace or fire brand and hold it directly in the path of the steam blast. The oil fuel valve is now opened, permitting the oil to flow through the partly-opened needle valve and the spray of atomized oil thus formed will be ignited by the burning waste. After the spray is once ignited, gradually increase the quantity of steam and fuel. As the temperature of the furnace rises with the increased rate of combustion and gradually reaches the maximum, adjust the burners and damper for proper operating conditions.

To Start Up a One-Boiler Plant

Where the boiler to be started is the only one in the plant or in case all the boilers in a plant are shut down, it is obvious that some means must be provided to furnish oil pressure and air pressure for the operation of the burners. On shipboard a dummy boiler is usually installed for this purpose but in stationary practice other methods are employed. In small installations, say below 200-hp., it is possible sometimes to get up enough pressure by building a wood fire under the boiler. A better method, however, is to install an oil tank sufficiently high above the burners so as to provide a gravity head and a small air compressor with storage tank to furnish air pressure for atomizing the oil. Practically all steam-operated burners can use air for starting purposes.

With mechanical burners, the process of starting is still simpler, as the only requirement here is to provide sufficient oil pressure, steam or air being unnecessary. This pressure is often furnished by a small hand pump.

With any type of installation it is important to avoid turning oil into a dark furnace, as the volatile matter in the fuel may quickly form an explosive mixture, which, when the burner is turned on, may result in an explosion. In any case, however, take the precaution first to open all the dampers so that any sudden pressure rise in the furnace may be relieved through the openings.

Control of Viscosity

To insure proper atomization at the burners, practically all fuel oils require that their viscosity be reduced by heating. The proper viscosity is a matter of experiment but ranges between 8 to 15 deg. Engler. Certain oils now marketed have to be heated above their flash point in order to attain the required viscosity. Oil of this kind is to be avoided, as the inflammable vapors driven off the oil above

the flash point are a continual menace. In buying oil, it should be specified in the contract that the oil must attain proper viscosity at a temperature below the flash point.

Two things are accomplished by heating oil; first, it enables the viscous fuel to be handled more easily and, second, it reduces the amount of steam necessary to atomize a given amount of fuel. This is due to the fact that the internal resistance of the oil is considerably reduced. The maximum temperature for this service is between 180 and 220 deg. F.

According to the Bureau of Mines, there is a great tendency, in practice, to overheat the oil. In a bulletin, "Efficiency in the use of oil fuel" they state that the capacity of a burner increases as the oil is heated to a certain temperature, determined by the viscosity and the expansion relation but, with further increase of temperature, the capacity steadily decreases. This relation between the temperature of the oil and the capacity of the burner is shown in Fig. 1 taken from the Bureau of Mines' bulletin. Here it will be noted that the capacity of the burner increases as the temperature of the oil is raised from 80 to 112 deg. F. but above that the capacity rapidly decreases. This chart, of course, applies only under the condition stated and must not be construed as applying to all oils. The operator of an oil-burning installation should always know the temperature to which his oil should be heated to secure the best results.

Heating of the fuel oil is usually done by steam, in closed heaters designed for the purpose. In some cases, heating is accomplished by merely installing a steam coil in a vessel of oil but this is not satisfactory, as it tends to local heating. A number of types of heaters are available. The corrugated film type shown in Fig. 2, is

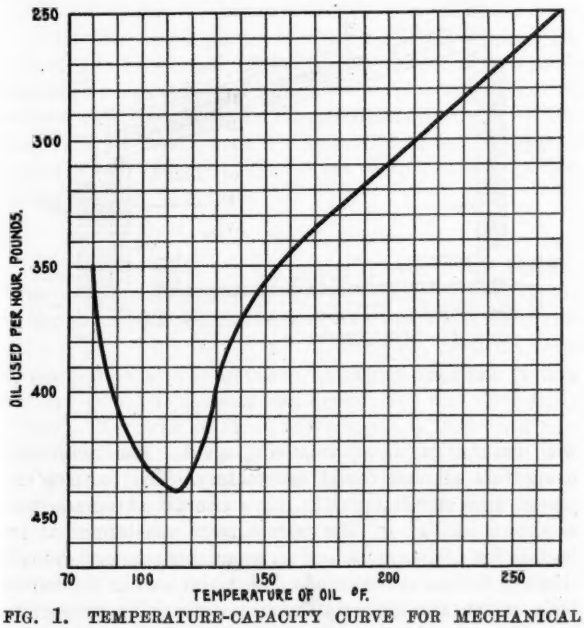


FIG. 1. TEMPERATURE-CAPACITY CURVE FOR MECHANICAL OIL BURNER. TEXAS CRUDE OIL (GRAVITY 18 DEG. B. FLASH POINT 240 DEG. F.)

shown because it incorporates correct engineering principles in its design and in practice has shown excellent rates of heat transfer. It consists of two spirally-corrugated copper tubes *a* and *b*. These fit closely, leaving only a thin space between them and the oil is led into this space through inlet *c*. Steam is admitted through the pipe *e* and flows directly into the interior *f*. Other types of heaters are shown in Fig. 3.

It is one thing to heat the oil and another to keep it at the desired temperature until it reaches the burners. Usually the temperature can be maintained by covering the oil lines with a suitable thickness of heat-insulating material but where the lines are long, an exhaust steam line is run through the center of them. A simpler method and one that is almost as effective is to install the exhaust steam line next to the oil line within the same insulating covering.

In some cases, it is necessary to heat the oil in the storage tank, particularly where the installation is in a cold climate. There are crude oils that, at temperatures of from 30 to 40 deg. F., become so sluggish that they

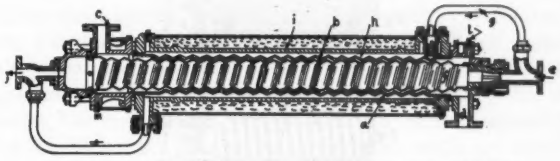


FIG. 2. CORRUGATED FILM TYPE OF OIL HEATER

cannot be drawn to the pump. In cases of this kind, it is usually sufficient to install a heating coil around the lower end of the suction pipe. This will heat the oil in the immediate vicinity of the entrance to the pipe and enable it to be drawn.

Control of Air Supply

Regulation of the air supply to an oil-burning furnace is extremely important, as a great part of the success of an oil burning installation depends upon the degree to which the air supply is maintained at its proper value. It does not matter how well the burner does its work, if the required air is not admitted at the proper time and place, the oil cannot be burned efficiently. In regulating the air supply, the object is to admit just enough for complete combustion and no more. The air should be admitted not only in proper quantity but at the proper point in the furnace, so that the flame will burn with just as near theoretical air requirements as possible.

Combustion is a chemical reaction. It is the rapid chemical combination of oxygen with the carbon, hydrogen, and sulphur in the fuel, resulting in the liberation of energy in the form of light and heat. A definite quantity of oxygen is required for the complete combustion of each constituent combustible element in the fuel. About one-fifth of the air by volume is oxygen and the exact amount of air required to furnish oxygen enough for complete combustion of the fuel can be computed from an analysis by means of the following formula: Pounds of air per lb. of fuel $= 11.52\ C + 34.56\ [H - (O \div 8)] + 4.32\ S$. Where, C, H, O and S are the percentages by weight of the carbon, hydrogen, oxygen and sulphur in the fuel.

For practical purposes, however, the Bureau of Mines states that the quantity required theoretically averages about 14 lb. of air to the pound of fuel. "In practice," quoting further from the Bureau of Mines, "it is not possible to burn oil with only this exact quantity of air, 100 to 200 per cent excess being sometimes used with a resulting great loss of heat." With good design 25 per cent

excess should be the maximum. No evidence of loss of heat from excessive air supply can be had by watching the stack, for there will be no smoke, if the carbon fully combines with oxygen to form CO_2, as the excess air is invisible.

Where to Introduce the Air

The correct point for the introduction of air in any oil-fired installation does not vary and requires but little work to locate once we know where to look. In a properly constructed furnace, the temperature carried is such that the

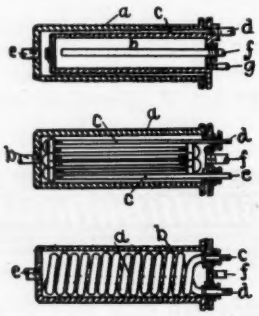


FIG. 3. THREE TYPES OF FUEL OIL HEATERS

atomized fuel ignites from 12 to 15 in. in front of the burner tips. This point, where the temperature of the furnace is sufficient to ignite the fuel, is the theoretically correct place to admit all air for combustion.

To accomplish this, a good method is to supply each burner by means of a separate air duct, installed, preferably, under the floor of the furnace and opening into the furnace at a point below the burners, so that the emerging air will be forced directly into the path of the gases. The more thorough the introduction of the air into these gases, the more complete will be combustion. In all cases, it is important to enter the air for combustion under the path of the gases—never to the side or above.

A furnace which has given good results in burning oil is shown in Fig. 4. Here the air duct, as will be noted, runs under the floor, permitting the air to be heated before its introduction into the furnace. A small wall is installed at the opening of the air duct, just under the burner, so as to deflect the air for combustion directly into the path of the gases emitted from the burner.

Another common method of supplying air to an oil-fired furnace is by means of a checker-work formed in the brick work of the furnace floor. This method is effective, if the checker-work is properly designed, otherwise it can be extremely wasteful. Some interesting tests were reported to the N. E. L. A. Prime Movers Committee some time ago, which illustrates the importance of proper checker-work design to a high degree. These tests were made on a 686-hp. B. & W. boiler with front short steam-atomizing burners. A simple change in the number of openings and the manner of arranging the openings in the checker-work increased the output from 140 per cent to 150 per cent, raised the CO_2 from 12 per cent to 14.2 per cent and reduced the flue gas temperature from 570 to 530 deg. F. The nature of the changes made during this test are indicated in Fig. 5.

Actual regulation of the air supply is accomplished in several ways, depending upon the arrangement at any particular plant. Forced draft is not suitable for steam or air-atomized oil firing because there is no fuel bed to offer resistance, as in a stoker fired furnace. Induced draft fans, however, are used to good advantage, where sufficient natural draft is not available. In such plants, the air supply can be controlled partly by the speed of the induced draft fan, partly by the damper at the outlet to the boiler and partly by the dampers in the air ducts to the furnace.

Where mechanical burners are installed, the use of forced draft is common and, in many installations, each burner is surrounded by an air duct leading to a blower or to a loop supply line under pressure from a blower.

Where natural draft is used, the air supply is regulated entirely by dampers in the air supply ducts and in the outlet to the boiler. When the stack damper alone is used, the air ducts to the furnace are left wide open and the rate at which air flows into the furnace is regulated by the amount of opening of the damper. With this method, opening for the admission of air is always ample and it enters at a rate sufficient to replace the gases escaping to the stack. In most plants, however, regulation is obtained by varying both the stack and air supply dampers.

Gas Atomizing Burners

In connection with the matter of oil burning, it may be of interest to mention a new development, reported by the Prime Movers Committee of the N. E. L. A., in which oil and gas are burned simultaneously by means of a gas-atomizing burner. Gas, as an atomizing agent for fuel, has been suggested at various times, but little or no experimenting had been done along this line. Early in 1923, however, a series of experiments were begun at the East Waco station of the Texas Light Co., where oil was used

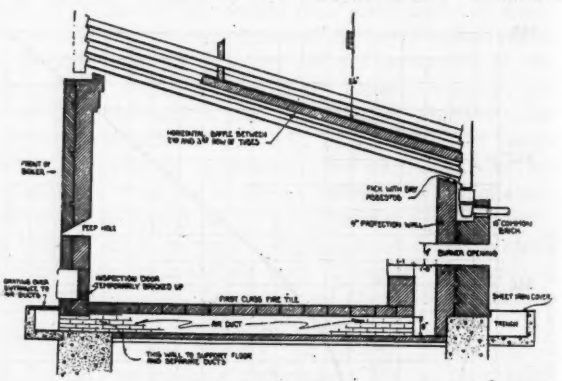


FIG. 4. FURNACE USED FOR BURNING OIL THAT HAS GIVEN GOOD RESULTS

with natural gas as an atomizing agent. This method of using fuel oil was found satisfactory. The burners employed were the Leahy Mfg. Co.'s size 2B burners altered as shown in Fig. 6. The burner body was tapped at the bottom for a ¾-in. pipe and an atomizing connection made through the tee as indicated. The ⅜-in. hole in the burner body, which was formerly the steam atomizing connection, was plugged. At the outer end of the burner atomizing piping connection a 1-in. tee was cut into the line and connection made to bypass the valve body. The 1-in. outlet on the tee was then connected to the gas supply header while the connections were made to the oil and steam lines in the usual manner. In this way, it was possible to change from atomizing with gas to atomizing with steam by simply closing the bypass gas valve and opening the steam

valve. Tests were made under a 6000 sq. ft. B. & W. boiler. The gas used had a specific gravity of 0.650 and a calorific value of 1000 to 1100 B.t.u. per cu. ft. The oil used was about 25 deg. Baume Texas fuel oil with a calorific value of 19,000 B.t.u. per lb.

With this equipment, it was found possible to operate at ratings up to 170 per cent, 20 to 40 per cent of the total heat being contributed by the natural gas atomizing medium, with as good combustion as when using either gas or oil alone. The conclusions drawn from the tests were:

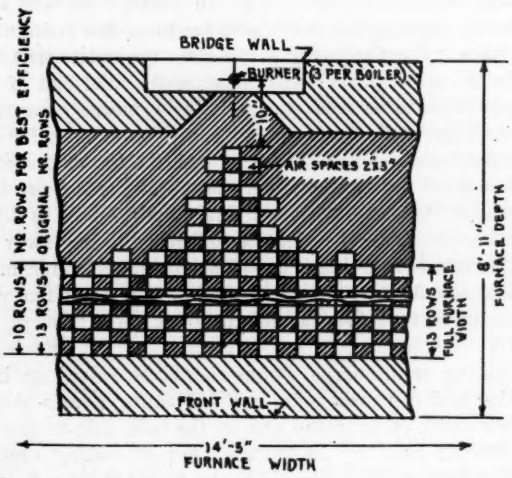


FIG. 5. PLAN OF FURNACE SHOWING CHANGES IN ARRANGEMENT OF AIR OPENINGS WHICH GREATLY IMPROVED OPERATION

(1) That under proper conditions a combination of gas and oil can be burned efficiently. (2) That, with suitable furnace and burner design, any proportion of gas and oil within wide limits may be burned satisfactorily. (3) The desirability of using such a combination is mainly an economic question, depending upon the relative cost and availability of these two fuels.

Care of Burners

Oil burners, both the mechanical and the steam or air-atomizing types, should be carefully watched as they are liable to become clogged with foreign matter and coated with carbon. This may result in diverting the flame from its normal path, causing poor combustion. For this reason, burners should be disassembled periodically and thoroughly cleaned. Kerosene is an effective agent in removing carbon. When burners have become clogged with solid matter, due to faulty strainers or to carbonizing of the oil, they should be removed and blown through with steam or else replaced. Irregularities on the inside or outside of new burner tips, especially in the case of mechanical burners, often cause streaks in the flame. Such irregularities may be eliminated by polishing with a hardwood stick and a paste of light oil and finely powdered glass. Emery is too coarse and will cut the metal. The stick is filed down to fit the orifice.

It is well always to keep a number of spare burners on hand, ready for instant use when one of the burners shows defective operation.

It is generally agreed among combustion engineers that a smokeless stack is no evidence of efficient combustion or even of complete combustion. There is a common belief that the contrary is true. Smoke, it is true, is evidence of waste and is unnecessary but a clear stack may also represent waste because of great excess air losses in spite of the fact that combustion may be complete.

A stack gas showing just hazy, although it indicates slightly incomplete combustion, is the safest check on the operation of an oil-fired plant, when an analysis of the flue gas cannot be had. An accurate analysis of the flue gas is, of course, the only certain way of checking combustion effectiveness.

To the experienced operator the appearance of the flame in the furnace gives a rough indication of combustion conditions but too much reliance must not be placed upon it. A short flame may indicate oversupply of air. In any installation, the furnace length should be greater than the horizontal length of the flame, because the length of the flame cannot be easily controlled, except by operating the burners inefficiently with a high percentage of excess air. That furnace arrangement which will give the longest gas travel, without direct impingement on brick work or boiler heating surface, is the best and most economical for burning oil. Bridge walls, checker walls or target walls should not be used.

A dazzling white flame also may indicate too much air; certainly the white portion should not extend back more than 6 in. from the burner, after which it becomes transparent, runs into violet, and towards the end changes to red. With too little air, no violet is seen, the red darkens and smoke appears. Streaks in the flame, as stated before under care of burners, indicate dirty tips.

An oil burner in operation produces a characteristic roaring noise, which may also serve as a guide in judging combustion efficiency. Introduction of an excessive amount

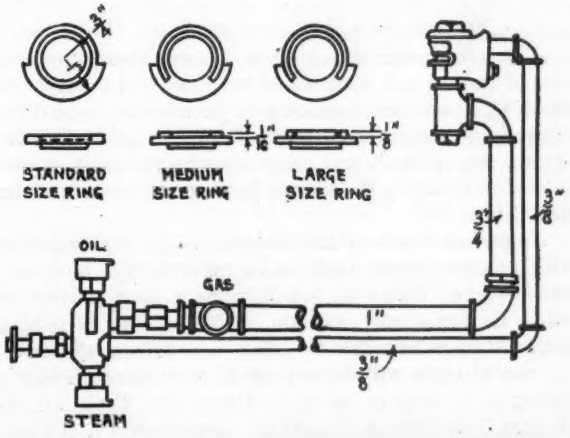


FIG. 6. DETAILS OF GAS ATOMIZING OIL BURNER

of cold air greatly increases the noise. Preheating of the air to a higher temperature, on the other hand, results in quiet combustion. A quiet furnace, therefore, would seem to indicate more efficient combustion, since it is obtained by reducing the excess of air and by increasing its temperature.

It is never safe, however, to rely too much on visual or aural indications and, if definite information regarding combustion efficiency is desired, it is necessary to analyze the flue gases frequently. The exact position of the damper to suit different loads can only be determined by flue gas

analysis. The CO_2 content of the gases should be maintained as high as possible without the production of CO. It should be possible to secure 13 to 14 per cent CO_2 without a trace of CO. If this cannot be done, an investigation of the burners and furnace arrangement should be made, as probably something is wrong with them.

Shutting Down the Furnace

Shutting down an oil-fired furnace is a simple matter if a few precautions are kept in mind. The first thing, of course, is to cut off the supply of oil to the burners. This is usually accomplished by closing the stop valve on the main oil supply line. Next, the steam valves should be closed until only a small jet of steam escapes from the burners.

Then the burner should be blown out so that no oil remains in it. This is done by opening first the oil-regulating valve on the burner, next the bypass valve and then the steam valve. If oil is permitted to remain in burners when not in use, it may carbonize under the action of the heat in the boiler setting and cause difficulty when service is started again.

Another precaution to be observed in shutting down an oil-burning installation is to prevent the too rapid cooling of the furnace brickwork by permitting cool air to enter the furnace. All draft openings should be closed and the damper opened so as to allow the furnace to cool slowly.

Once a furnace has been shut down, care should be taken not to turn on the oil supply to the burners, except where the flow has been interrupted only a few seconds. In that case, usually, sufficient heat is stored in the brickwork to re-ignite the spray when it is turned on. If the supply has been cut off for some time, there would not be sufficient heat to effect ignition and a dangerous explosive mixture would form.

Storage and Handling of Fuel Oils

Like many other things about a power plant, the question of storing and methods of handling fuel oil must be decided in each case according to purely local conditions. Capacity of station, availability of fuel, price of fuel, insurance requirements and many other factors must be considered in planning the storage facilities for any particular installation.

In cases where the plant is located near a supply station with proper delivery facilities, a small storage tank may be sufficient. Where oil has to come a long distance or where deliveries are uncertain, it is necessary to provide larger storage capacity to avoid unnecessary shutdown.

Size of tanks will depend too upon whether the fuel is delivered by truck or by railroad tank car. Tank cars are in sizes from 6000- to 12,000-gal. capacity and it is necessary to have a tank capable of holding at least the capacity of one car. It is well also to divide the storage into at least two tanks so that one may be cleaned or repaired when the other is in use.

In comparing steel or concrete as materials of which to construct storage tanks for fuel oil, there is some difference of opinion. Steel seems to find more adherents, although, in late years, the use of concrete has become more popular. There seems to be a belief that concrete deteriorates under the action of oil but there is little foundation for this opinion.

Underground storage tanks have an advantage in regard to fire hazard, but a steel tank above ground is more readily inspected. Where the plant is of considerable size, it is common practice to use a moderate size underground tank near the boiler room as a service tank with a larger one above-ground as the main storage tank. The underground tank presents several advantages over the above-ground tank. It permits filling from trucks or tank cars by gravity and prevents the possibility of flooding the furnaces or boiler room, in case a burner valve is accidentally left open.

Connections should be provided in the storage tank for inlet and outlet, for drainage of water and sediment, for a heating coil inlet and outlet, for an atmospheric vent and, wherever possible, for steam and fire-foam fire extinguishing lines. For the outlet a swinging connection is to be preferred, a two-elbow joint allowing the inlet end of the suction pipe to be held at any level by means of a cable through the roof or top of the tank. Steam lines for fire fighting should be brought in through the top of the tank, with a goose neck higher than the top of the tank so that oil cannot flow into the steam line when the tank is filled.

The vent should be of a size sufficient to carry away air at the greatest rate that it can be displaced by the incoming oil and should have its end covered by a piece of fine wire gauze to prevent fire flashing into the tank through the vent.

Filling or discharge pumps should be valved on both suction and discharge sides and the filling pumps should have a check valve in the line on the tank side to prevent oil flowing back to the pumps. For unloading cars by gravity flow, a 10-in. line should be provided, as a 3- or 4-in. flexible connection will increase the unloading time 6 to 8 times.

Special Precautions for Safety

Because of the inflammable nature of fuel oil, rendering accidental fires or explosions a possibility, special caution should be observed in handling it. Certain precautions have already been discussed, such as the provision of gauze coverings over the vent pipe on the storage tank and the use of steam and fire-foam fire fighting lines. In providing vents, it is important to allow for carrying away all vapor that may be formed from the oil due to exposure to internal fires. Sufficient data has not been obtained to formulate rules in regard to size of vents but it has been found that, while a 40-mesh screen works well for small pipes, it is not good for larger ones.

Except where mechanical atomizers are used, the burners should be of such type as to prevent the possibility of enlarging the orifice. It should also be impossible to unscrew and remove the needle valve while the burner is in operation. As soon as a burner gives evidence of becoming dirty, it should be removed and cleaned.

To prevent flarebacks, the following precautions should be kept in mind: Do not permit oil accumulation on the furnace floor; keep burner control valves tight at all times but, if any oil does get into the furnace, wipe up the floor and blow out the furnace with air before starting up; always use a torch when lighting a burner. In the event a flareback does occur, close the master oil valve, speed up the blowers, if in operation, and shut off the oil pump.

Should oil escape from the lines and become ignited, it is, of course, useless to attempt to extinguish it with water. If no chemical extinguishers are at hand, smother the flames with sand or earth.

Hand Firing for Power Boilers

PERSONAL ELEMENT MORE OF A DECIDING FACTOR IN FUEL SAVING THAN WITH POWER STOKERS

EDUCATIONAL campaigns by various industrial and engineering organizations have done much to increase the efficiency of hand-fired plants, yet there is considerable room for improvement.

One point most often overlooked by chief engineers and other executives is that no manner of instruction will make men want to save fuel unless they have some incentive. Bonus systems have worked wonders in many plants and should be more generally adopted. But in numerous plants such systems cannot be used until apparatus is installed to keep a check on the performance of the different operators. In a number of plants, more often hand-fired, the only instrument for the guidance of the firemen is the steam pressure gage and this is required by law.

Before an operator can tell whether any of the instructions which he reads is helping him, he must know just what his boiler and furnace will do with old methods and then compare the record with that from new methods; after he has grasped new methods, he should have recording instruments to compare one day's operation with the next.

Nowadays a wide-awake manufacturer wouldn't think of doing business without a cost system. He also has record systems to keep account of how material is used from stock; why shouldn't a power plant operator know what his heat units cost and where they are going? A steam flow meter or water meter, a draft gage, and a CO_2 recorder, or a combination steam and air-flow meter should be recognized as needed equipment in every boiler room, large or small.

Hand-Operated Stokers

Hand stokers have been developed more recently than power-driven types to get higher rating and better efficiency than with hand-firing, but where the expense for a mechanically operated stoker is not warranted.

In many respects, these stokers resemble the overfeed gravity type, having a coking hearth at the top and feeding down upon tilting bars which work the fuel towards the dump plate. They require more attention than power stokers since the attendant must frequently operate the levers which work the fuel towards the bottom of the incline. Nevertheless, the amount of labor of ordinary hand-firing is greatly reduced as the distribution of fuel is easier and the work of cleaning the fires is less difficult. Natural draft is used.

Practically all kinds of coal may be used on this type of stoker, inasmuch as the hearth and arch insure ignition and distillation of the volatile gases and, if coke is formed, it is broken up by operating the bars. The fire is kept clean by ash dropping through the grate bars as they are worked, the clinker being removed at the dump plate.

While the operation of the hand stoker is comparatively simple, certain well-defined methods must be followed, if the best results are to be secured.

In starting the fire on a hand stoker, such as shown in Figs. 1 and 2, cover the grates with about 3 in. of lump coal. On top of this throw enough wood to start the fire and ignite this wood with oily waste. If started in this way, the coal will burn from the top of the bed to the bottom, thereby causing little smoke. The air shutter in the fire door should be left open when starting the fire.

When firing, heap green coal about 10 to 12 in. thick on the upper end of the grate, the bank starting at the edge of the dead plate and extending downward about 18 in. The coal is left in this position to coke, until it is

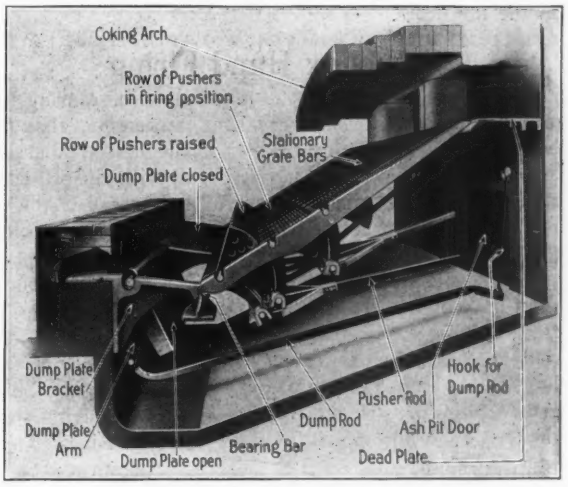


FIG. 1. REPRESENTATIVE TYPE OF HAND STOKER

time to put in another charge, but before doing this the coked coal at the top should be pushed down onto the pusher bars by means of a short-handled hoe or the back of a shovel. This fuel is then moved downward and enters into successive stages of combustion by the action of the movable grate bars.

Any kind of coal, coke or wood refuse may be burned. Slack coal of the hard-caking variety burns as readily as selected nut or egg size.

METHOD OF CLEANING FIRE

In cleaning the fire, drop both the dump plates and allow them to swing back against the bridge wall. If the clinker and ash do not fall through, pull the lever operating the lowest row of pushers, which will knock the clinker and ash off the bottom end of the grate. If the clinker is bad and bridges across the dump plate, raise

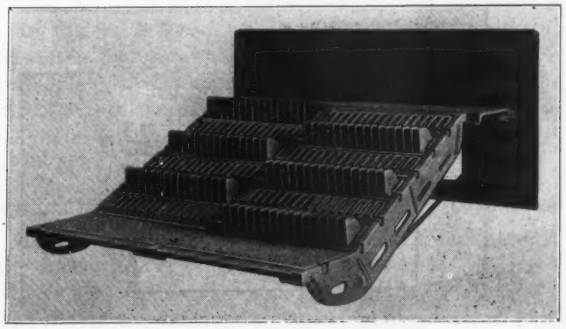


FIG. 2. FUEL IS MOVED IN SUCCESSIVE STAGES BY ALTERNATE ROWS OF GRATE BARS

the dump plate and break the clinker. After the clinker and ash drop into the ash pit, raise the dump plates and operate the lowest row of pushers and then the next higher in succession. This cleans the dump plates and the lower end of the grate; then push down the coal at the top end of the grate and fire as before. Just before cleaning, it is advisable to have a good quantity of hot coals at the top of the grate.

To bank the fire, it should be pushed down upon the lower end of the grate and dump plates, leaving the upper end of the grate bare. Cover this well with green coal; close the damper and the ash pit doors and open the vents on the fire doors.

Orthodox Hand Firing

Regardless of how much care is taken in securing the proper control of the air supply, it is necessary that the fuel feed be properly controlled, if the best combustion is to be attained. This is more difficult with the orthodox methods of hand firing than with hand-operated stokers.

Practically any kind of hand-operated stoker is better than ordinary hand firing and, if it is at all possible, plant owners should seriously consider some of the more modern ways of firing.

For those who perhaps have no choice and must still contend with hand firing problems, considerable increase in efficiency and subsequent saving may be effected by diligently following the accepted rules of hand firing, particularly those formulated by the Bureau of Mines. Those who are vitally interested are urged to obtain a copy of Technical Paper 80—Hand Firing Soft Coal Under Power Plant Boilers—by addressing the Director, Bureau of Mines, Washington, D. C.

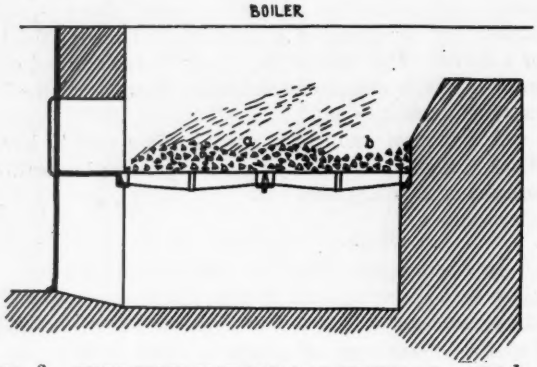


FIG. 3. THIN SPOTS MAY FORM AS SHOWN AT *a* AND *b*

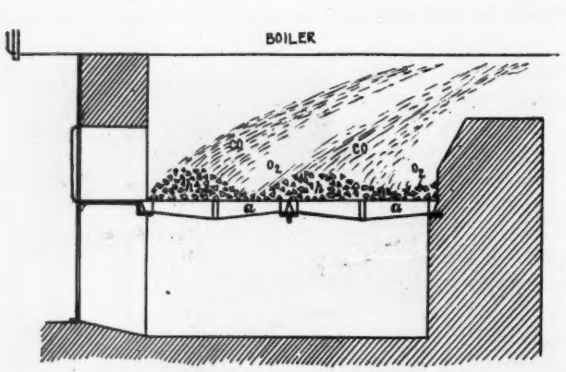


FIG. 4. FUEL SCATTERED EVENLY WITHOUT REGARD TO THIN SPOTS PRODUCES THIS RESULT

Three Methods Recognized

Three general methods are practiced in hand firing power boilers. The first method is that of firing large quantities of fuel at long intervals; this method is mentioned only because it is absolutely wrong, yet is used by many indifferent firemen. The second method is that of spreading 4 or 5 scoops of coal over one-half the grate and then waiting one firing period before firing an equal amount by the same method on the other half. With high volatile coal, it is necessary to open the fire door slightly for a few minutes after firing, in order to furnish sufficient air for smokeless combustion. Probably, this method is the most generally used because the fire doors are kept open for but a short period and it is easy for the firemen to quickly spot clinkers. The fuel bed is not disturbed, which is an important item with clinkering coal.

In the third or coking method of firing, the coked coal is cleared from the front third of the grate by pushing it back evenly over the back two-thirds. A large quantity of fresh coal is then fired on the front end. Gas is distilled from the fresh charge and is consumed as it passes over the incandescent coke bed. With this method it is difficult to keep holes from burning through the coke bed.

Thin Spots Should Be Covered

Firemen should be careful always to keep thin spots in the fuel bed covered. Thin and thick spots will occur even with the most careful firing, because the coal never burns at a uniform rate over the entire grate area. In places where the air flows freely through the fuel bed, the coal burns faster than in places where the flow of air is less. This may be caused by clinker or hard crusts in the fuel bed at various points. Where the coal burns rapidly, thin places form.

Figure 3 shows the conditions of a well-kept fuel bed immediately before firing; *a* and *b* are the thin spots over which the fresh coal should be spread. In order to fill up the thin places, the fireman should take a rather small quantity of coal on his scoop, for it is much easier to place the coal where it is needed with small shovelfuls than with large ones.

Coal should be placed on the thin places in rather thin layers. If the fireman attempts to fill up the deep hollows in the fuel bed at one firing, the freshly fired coal may fuse into a hard crust, thus choking the flow of air, causing the fuel to burn slowly and starting new high places.

If the fireman persists in spreading the coal evenly over

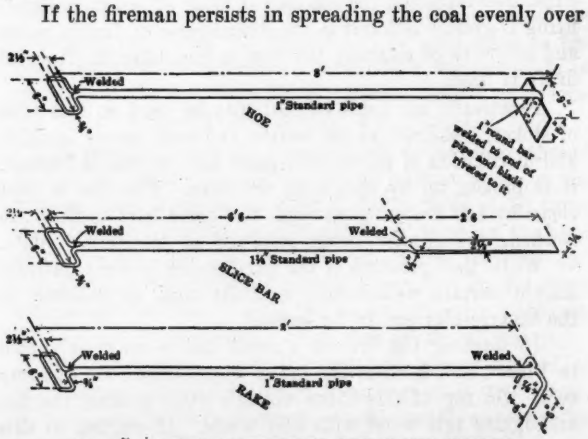


FIG. 5. NECESSARY TOOLS FOR HAND FIRING

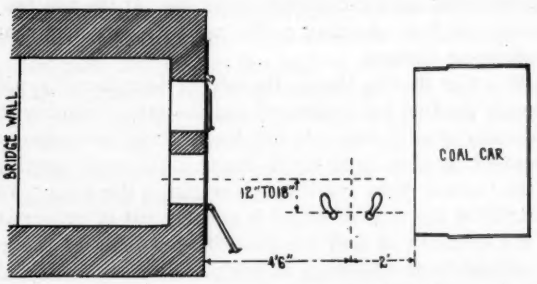


FIG. 6. FOOTPRINTS SHOW PROPER POSITION FOR FIRING

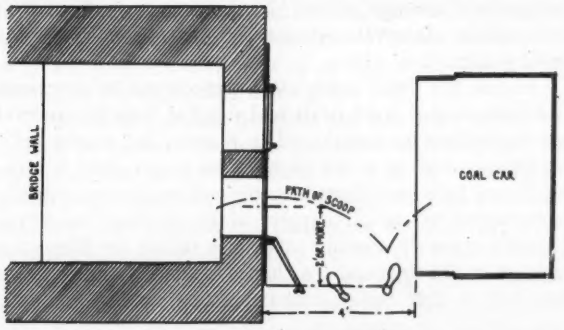


FIG. 7. FOOTPRINTS SHOW IMPROPER POSITION FOR FIRING

the entire grate area, the coal will accumulate in heaps in places where the flow of air is obstructed and, after several firings, the fuel bed will have the shape shown in Fig. 4.

This shows the heaps of coal, *h*, through which little or no air flows. But, as the fresh coal at the top of these heaps is heated, the volatile combustible is distilled off and rises in columns of smoke and combustible gas, which may pass out of the furnace only partly burned, unless the furnace is equipped with gas mixing structures. Between the heaps of coal are shown the thin spots, *a*, through which air passes freely, causing the coal in these places and around the edges of the heaps, *h*, to burn with bright flame. When the fuel bed gets into this condition, it is impossible to see the surfaces of the thin spots and difficult to place coal over them. There is great danger that some of these thin spots may become holes and admit a large excess of air.

The quickest way of making such fuel beds level is to break the caked coal forming the heaps and to spread it over the thin spots with the rake shown in Fig. 5. This leveling has its disadvantages. It puts extra work on the firemen, lets an excess of air into the furnace through the open firing door and is likely to disturb the ash and thus start troublesome clinker.

An unskilled fireman must rake his fires frequently to keep them level; sometimes the raking must be done after every other firing. Thus he handles the coal twice—once when he throws it into the furnace and again when he pushes it with the rake where it is needed. A skillful fireman can keep a fuel bed level for hours without raking, simply by placing the coal where it is needed. Thus it not only saves himself the work of leveling the fires but also avoids the formation of clinker, thereby reducing the hardest work to be done in the boiler room—cleaning fires.

Proper Position in Firing Important

In order to place the coal to best advantage, the fireman must take a proper position in front of the furnace, so that he can see the thin spots in the fuel bed and, with least effort, can throw the coal where it is needed. A proper position for firing the left door is shown in Fig. 6, the footprints showing where the fireman should stand. This gives him plenty of room to swing the scoop and so place the coal wherever he wishes. When in this position, at the end of the throw, the scoop can be stopped suddenly by laying it on the top edge of the fire door frame, so that the coal slides off the scoop and is scattered over the thin spot.

Figure 7 shows an improper position for firing. The fireman stands too near to the furnace and too far to one side. He cannot see the surface of the fuel bed and throws

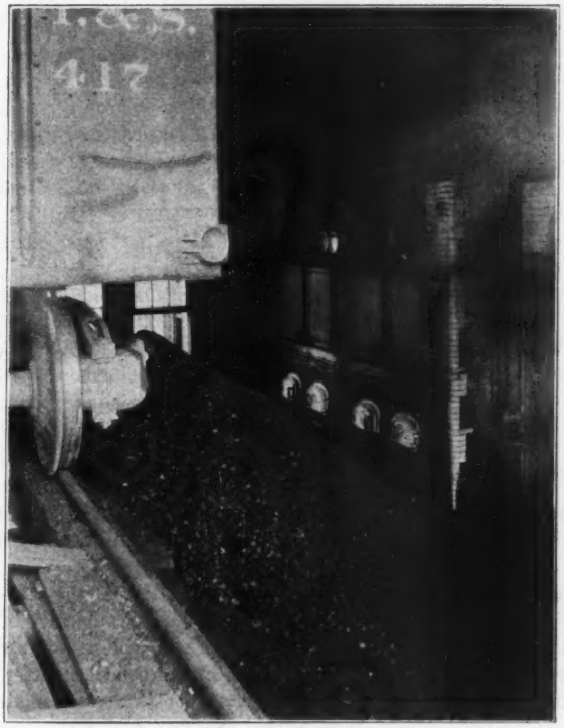


FIG. 8. COAL PILE IS SO NEAR THE FURNACE THE FIREMAN CANNOT HANDLE TOOLS PROPERLY

the coal in by guess; some of it falls off the scoop before the latter reaches the firing door, while that reaching the furnace is usually thrown over the front part of the grate where it accumulates in heaps. The rear part of the fire receives much less coal and frequently is full of holes.

In Fig. 8 is shown a view of a boiler room with the space even more crowded than in Fig. 7. Someone evidently thought that dumping the coal directly from the railroad car to the boiler room floor was an innovation in coal handling, but the labor saved by this method is wasted manifold in poor firing.

Small and Frequent Firing Periods Are Important

Bituminous coal should be fired in small quantities at short intervals. The quantities that should be fired vary with the size of the grate and the intensity of the draft. When the total available draft in the uptake is about 1 in. of water, 2 to 2½ lb. of coal per sq. ft. of grate is a fair average. Thus, on a grate 8 ft. wide and 6 ft. deep, each

firing would average 100 to 125 lb. of coal, or about 6 to 9 shovelfuls. Intervals between the firings should average about 5 min.

In case the draft is high, the periods can be shortened to 3 min.; with a weak draft and sluggish fires the interval may sometimes be lengthened to 8 min., but, under ordinary circumstances, it should never be longer than 10 min. Small and frequent firings keep the coal supply more nearly proportional to the air supply, which in most hand-fired furnaces is nearly constant; they also reduce the formation of crust on the fires and the chance of holes forming in the fuel bed, so that better combustion is secured.

Air Regulation

Immediately after firing, a quantity of air should be admitted over the fire sufficient to burn the volatile matter,

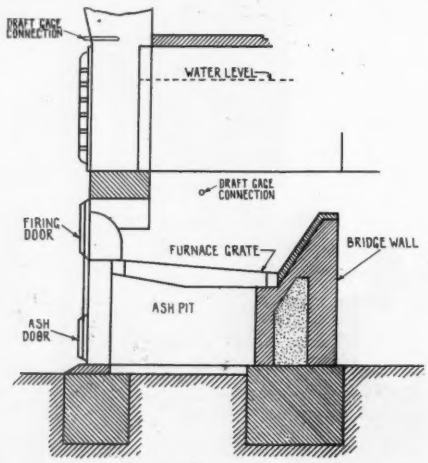


FIG. 9. THESE ARE PROPER LOCATIONS FOR DRAFT GAGE CONNECTIONS

this being gradually reduced as the distillation of the volatile matter nears completion. The larger the quantity of fresh coal fired at a time, the larger the volume of air needed for the complete combustion of the volatile matter. After distillation is completed, only a comparatively small quantity of air need be admitted over the fuel bed.

Regulation of the draft is best accomplished by using a damper in the uptake or breeching and it is better to have each boiler equipped with its own separate damper, so connected that the fireman can manipulate it when standing on the floor in front of the boiler. In many plants there are no such connections and the fireman must use a ladder to reach the damper; in consequence he seldom or never uses it. When the demand for steam is low, instead of keeping down the combustion rate by reducing the draft, he fires at longer intervals and permits holes to form in his fire, so that a large excess of air enters the furnace. This excess of air absorbs heat while passing through the furnace and carries the heat away through the stack. Damper connections for hand manipulation cost comparatively little and usually are easy to install.

Regulating Draft by Ash Pit Doors Is Bad

When there is no proper damper connection, the fireman often attempts to regulate the draft by closing the ash pit doors. By doing this he shuts off entirely the air supply through the fuel bed, so that the ash on the grate and the grate itself become heated. Doing this repeatedly may warp the bars and shorten their life. If the ash has a tendency to fuse, shutting of the ash pit doors may cause troublesome clinkers.

It is true that by closing the ash pit door the air supply through the fuel bed is shut off and the rate of combustion is thereby greatly reduced; but the draft in the setting is increased, so that more air is drawn in through openings in the furnace doors and through cracks in the walls. The quantity of air thus admitted is entirely out of proportion to the quantity of coal burned. Only a little of the air is utilized in the burning of fuel; most of it merely absorbs heat which it carries up the stack.

Use of the Draft Gage

It is impossible to determine the strength of draft from the position of the damper as in some positions it must be moved considerably to cause any noticeable reduction or increase of the draft; in other positions a slight movement may change the intensity of draft considerably. It is best to do away with all guesswork by connecting a draft gage permanently to the furnace and breeching, so that the intensity of draft can be read at any time. The draft gage itself should be placed at the front of the boiler, near the damper control, so that the fireman can read the draft while adjusting the damper. Proper draft gage connections are shown in Fig. 9.

Thickness of Fuel Bed

Thickness of the fire should vary somewhat with the quality of coal and the available draft. In plants where the available draft in the breeching is about 1 in. of water and where run-of-mine coal is used, the best thickness of fuel bed is 4 to 8 in. Under the usual operating conditions there is no reason why fires should be carried thicker than 8 in. and with some coal even this is too much. If the coal is coarse and contains only a small proportion of fines, the thickness of the fuel bed may be near 8 in., but, if the coal is mostly slack, better results are obtained with a thickness of about 4 in.

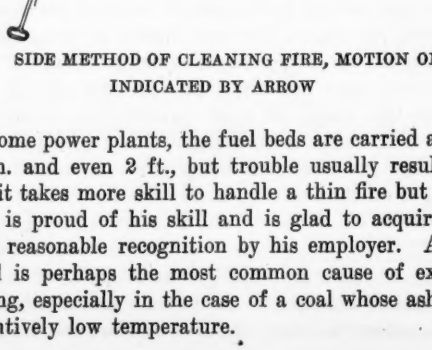


FIG. 10. SIDE METHOD OF CLEANING FIRE, MOTION OF TOOLS INDICATED BY ARROW

In some power plants, the fuel beds are carried as thick as 18 in. and even 2 ft., but trouble usually results. Of course, it takes more skill to handle a thin fire but a good fireman is proud of his skill and is glad to acquire it, if there is reasonable recognition by his employer. A thick fuel bed is perhaps the most common cause of excessive clinkering, especially in the case of a coal whose ash melts at a relatively low temperature.

Thin fuel beds do not let oxygen pass through unused unless they contain holes. The available evidence shows that the gases rising from the surface of a fuel bed 3 or 4 in. thick contain on the average less than 2 per cent of free oxygen and about 25 per cent combustible gas; that is, considerable air must be admitted through the fire doors and other openings to the combustion space in order to burn the combustible gases completely.

Cleaning Fires

In the hand-fired furnace, not only is the feeding of the coal a more or less intermittent process but the removal of the ash must be done at intervals. Part of the fine ash drops through the grate, but the coarse pieces and the clinker accumulate on the grate and must be removed. Removal of the refuse is called cleaning fires.

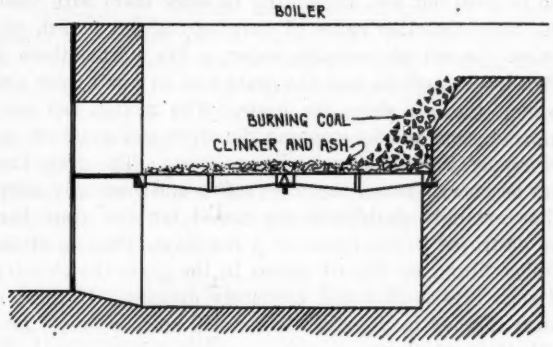


FIG. 11. FRONT TO REAR METHOD OF CLEANING FIRE

The tools used in handling fires are shown in Fig. 5. The hoe and slice bar are used principally for cleaning the fires, the rake being used only for leveling.

Intervals of cleaning depend on the proportion of ash in the coal, the character of the ash, and the type of grate. If the coal contains much fusible ash, the fires must be cleaned often. If a shaking grate is used or if the air spaces in a plain grate are large, some of the free ash can be shaken through the grate, thus reducing the rate of accumulation of refuse on the grate. If a light fire is carried, less clinker forms on the grate and, under such conditions, the fire can often be run through a day shift without cleaning.

Cleaning of fires should be done thoroughly; that is, all clinker and ash should be removed so that they cannot fuse to the side wall and the bridge wall and thus gradually reduce the effective area of the grate. The clinker and ash should be removed in such a way as to waste the least amount of combustible. This can be easily accomplished by separating the good coal from the clinker and ash, because the clinker and ash naturally sink to the grate, while the good coal remains on top.

Two methods of cleaning hand-fired furnaces are in general use; one is called the side method and the other the front-to-rear method.

Side Method of Cleaning

In the side method one side of the fire is cleaned at a time. The good coal is scraped and pushed from the side to be cleaned first on to the other side in the manner shown in Fig. 10. The arrows indicate the direction of the movement of the fire tools and of the burning coal from the rear left corner to the right half of the grate and also to push the coal from the front of the left half to the right half of the grate. In B is shown the use of the slice bar in scraping the coal, with an oarlike motion, from the left half to the right half of the grate.

If the clinker sticks, the slice bar may have to be run under it to loosen it from the grate and side wall and to break it so that it can be pulled out with the hoe. This loosening and breaking of the clinker should be done immediately after scraping the coal, while the slice bar is in the furnace, so as to save extra handling. When all the clinker is loosened and sufficiently broken, it is collected with the hoe on the front part of the grate, then pulled out of the furnace into a wheelbarrow set close to the furnace door.

When one side of the furnace is cleaned, the burning coal from the other side is moved and scraped to the clean side and then spread evenly over the clean part of the grate with a hoe, several shovelfuls of fresh coal being added to provide sufficient burning coal to cover the entire grate when the cleaning is done. This adding of coal is important, especially when cleaning must be done with the load on the boiler.

Clinker is removed from the second half of the grate in the same manner as from the first half. When cleaning is started, the fuel bed should be thick enough so that there will be sufficient burning coal left to start a hot fire quickly when the cleaning is completed. If a light fire is carried, cleaning may be started without waiting for the fire to burn down. In fact, it may be necessary when starting to clean to put some fresh coal on the side to be cleaned last. During cleaning the damper should be partly closed.

After a fireman has become familiar with the side method he is able to clean the furnace of a 200-hp. boiler in 10 to 12 min.

Front-to-Rear Method of Cleaning

In the front-to-rear method of cleaning, the burning coal is pushed with the hoe against the bridge wall instead

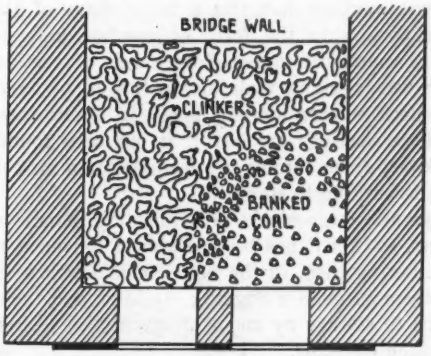


FIG. 12. METHOD OF BANKING NEAR ONE OF THE DOORS

of being moved to one side. Usually it is preferable to clean one-half of the grate at a time unless the furnace is small and has only one fire door. Figure 11 shows the burning coal pushed against the bridge wall and the clinker and ash ready to be pulled out. The clinker is loosened and pulled out in the same way as in the side method of cleaning. After the exposed clinker has been removed, the burning coal is pulled forward onto the bare part of the grate with a hoe and leveled. Fresh coal is then fired

and the fuel bed is ready for the continuation of the regular run.

The front-to-rear method of cleaning is somewhat quicker than the side method, but it is not so thorough Some clinker is always left at the bridge wall, gradually growing toward the front and reducing the effective grate area. When the boiler is worked hard, this growth of clinker near the bridge wall will cause shortage of steam and finally may cause a shutdown. Therefore, if the front-to-rear method of cleaning must be used while the boiler is under a heavy load, the side method should be employed after each day's run, so as to prevent large accumulation of thick and hard clinker on the bridge wall.

Banking Fires

In plants where the fires are banked overnight, the after-shift cleaning should be done early in the morning; say 2 hr. before steam is needed. This gives the clinker time to cool off so that it can be removed easily. In order to give the clinker near the bridge wall a chance to cool off, it is advisable to bank the fire on the front part of the grate near one of the fire doors, as shown in Fig. 12. In the morning the exposed cool clinker can be pulled out without the previous handling of any burning coal. After the clinker is removed, the banked coal is spread over the cleaned part of the grate, and whatever refuse was left under the banked coal is pulled out. With banked fires the damper in the breeching should be nearly but not quite closed.

Grates Should Have Sufficient Air Space

In most plants burning soft coal, grates containing large air spaces are not only better but are necessary for the majority of coals. The air spaces should be not less than ½ in. wide, and for some coals should be as wide as ¾ in. The percentage of air space should be as high as possible without weakening the grate. Grates with 100 per cent air spaces would be the best, if that were possible. These figures regarding air spaces in grates apply only to bituminous coal. For lignite and the small sizes of anthracite the air spaces may have to be smaller.

Burning Coal in the Ash Pit Injures Grates

Burning coal in the ash pit is often the cause of sticky clinker. Usually, such coal is shaken through the grate in the leveling of thin fires. Allowing holes in the fuel bed to burn out and attempting to cover them with fresh fine coal is another cause of burning coal in the ash pit. Unless the ash pit contains water, a fire started there is often hot enough to heat the grate bars to a red color and to melt the ash above the grate. The molten ash runs into the grate and by stopping the air spaces shuts off the air supply, thus making conditions worse. The grate bars may become so heated that they soften and gradually warp. Thus not only shutdowns are caused but the grate bars are destroyed in the course of a few days. Because of the clinker filling up the air spaces in the grate the cleaning of such fires is slow and extremely difficult. If there is much sulphur in the coal clinker will corrode or combine with the grate bars.

Special Furnaces Required for Wood Waste

Means for Handling Wood Waste; Requirements for Combustion; Features of Furnaces and Grates

SAWDUST, shavings, strips and blocks all make good fuel, but each has characteristics which influence, to some extent, the methods used throughout the entire system of conveying, storing and burning the fuel.

In woodworking factories a large share of the wood waste is usually in the form of sawdust and shavings. These are commonly gathered by means of suction hoods over the woodworking tools and delivered by fans to cyclone collectors over storage bins. In some cases, however, where shavings are heavy, it has been found advisable to sweep them into chutes leading to an air-conveying system discharging to storage.

Strips and large blocks are difficult to handle with air conveyors, so that it has become almost universal practice, after gathering them in the most convenient way possible, to run them through a hogging machine, and then deliver the chips to storage by means of an air conveying system and cyclone collector.

Several difficulties have been encountered in designing a storage bin from which to feed the wood waste to the furnaces. In some plants the amount of wood available for fuel is limited and no bin is provided, the chute from the cyclone delivering to the firing floor, from which the fuel is fired by hand.

Because of the inflammability of such fuel, the location of the storage bin with respect to the furnaces is of extreme importance. When the furnaces are to be fired by hand, the preferred location is across the aisle from the furnaces with the shoveling holes directly in front of the fire doors. Hand firing is not recommended, however, except when the amount of refuse is so small that it supplies only a part of the fuel needs.

When some mechanical means of feeding the fuel is employed, the chief consideration in the location of the bin is to provide means for preventing fire from traveling from the furnace to the fuel in storage. In most cases, if a large amount is likely to collect in storage, the bin should be separated from the boiler room by a fireproof wall, to prevent fires spreading from the furnaces to the fuel in storage.

One method of feeding the fuel from the bin to the furnaces, which has worked successfully, is by means of a drag chain, the arrangement being as shown in Fig. 2. Here, it will be noted, the storage bin is at the side of the boiler room and the drag chain passes through a trough in the bottom of the bin. The amount of fuel carried is regulated by two gates, one of which is fixed and the other movable. The feed gates to the furnaces are adjusted to divide the fuel properly among the furnaces. Over travel of the drag chain is provided to the left where, if there are any burning chips carried over, will do no harm.

Another system commonly employed makes use of a screw conveyor to deliver the fuel from the storage bin to the furnace. In this case the most convenient location for the bin is usually in front of the boilers with a conveyor feeding directly to each fuel chute to the furnace. The precaution to be observed in this arrangement is to have the conveyor long enough so that a fire started in

the discharge end will not travel back to the bin. Usually a half dozen turns of the screw is sufficient distance from the discharge to the bin. With this type of feeder, regulation of the amount fed is accomplished by varying the speed of the conveyor. A friction disk makes a convenient variable speed drive.

Still another arrangement which allows flexibility in location of the bin is used successfully in a number of plants. This consists of a screw conveyor for taking the fuel from the bin and delivering it to the suction of a fan which blows it into the furnace. By this arrangement only one screw conveyor is required and the fan can feed several furnaces by means of proper piping layout. The precaution to take with this system is to provide a check valve arrangement which will prevent a flashback from the furnace.

Considerable trouble has been experienced in some plants due to the fuel bridging over the discharge conveyor in the storage bin. Experience indicates that, in the design of a bin for wood waste, the conveying sides of the bottom should be at different angles. To insure even feeding to the conveyor, it is frequently placed under a hood in the bin, thus packing over the conveyor is prevented. Baffles in the bottom of the bin over the conveyor are sometimes used to serve the double purpose of preventing bridging and packing.

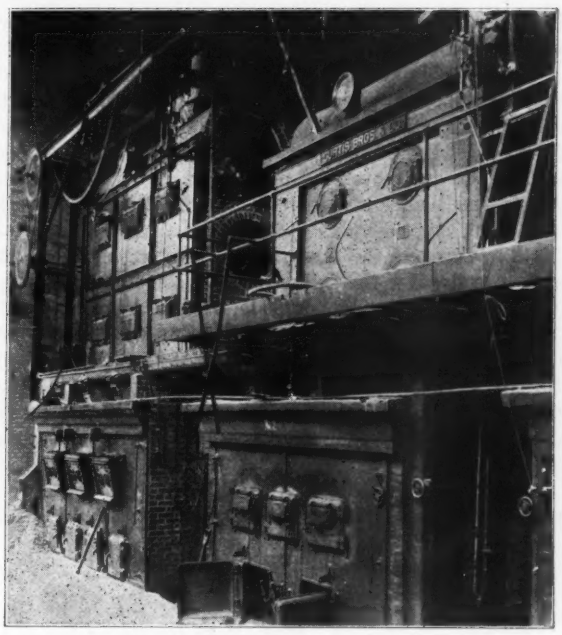


FIG. 1. THESE FURNACES BURN KILN-DRIED WOOD WASTE

Combined Wood and Coal Burning

Originally wood waste was burned for the sole object of getting rid of it around the plant. At that time no thought whatever was given as to the design of a furnace fitted for this purpose. The furnace was naturally designed as a coal burning furnace and the wood waste was thrown into the furnace on a bed of coals with resultant inefficiency, wastefulness of both wood and coal and the matter of feeding was laborious, so that the quicker the wood was burned the better satisfied were the workmen. As a usual thing, hand-firing was employed and the wood waste shoveled in through the firing door in large quantities, either with a shovel or a coke fork.

When it was discovered, however, that this wood had a real fuel value, better means of collecting and preparing the wood waste for burning were provided. Wood waste was then stored in bins, from which it was fed by various methods to the furnace, which was changed somewhat in design to get better results from the combined fuel used. With this method, it was customary to feed the coal by hand, as is the practice today in many plants where a small amount of coal is required.

In cases, however, where the amount of wood refuse is a comparatively small part of the fuel requirements, stokers are being used to advantage. These may be of either the chain grate, underfeed, front or side feed type. When the chain grate stoker is used, the wood is fed through the arch on the green coal in the front of the furnace. Where the furnace is wide, two feed chutes are employed, in order that proper distribution of the fuel may be had across the furnace. This method of feeding the

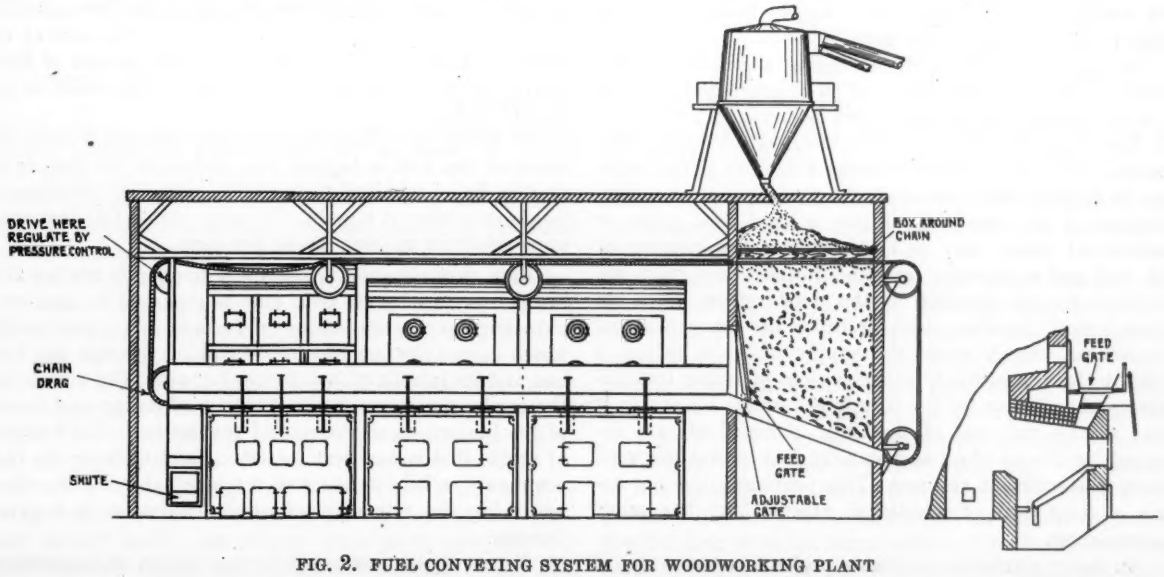


FIG. 2. FUEL CONVEYING SYSTEM FOR WOODWORKING PLANT

fuel has some disadvantages in that it is difficult to secure an even fuel bed in the furnace.

Results obtained by the use of underfeed stokers for supplying the coal requirements and wood waste fuel have been found satisfactory in many plants. In such cases forced draft is used to supply the air through the fuel bed, so that the draft over the fire is low. As a consequence, only a small amount of air is drawn in with the wood waste and little loss, due to secondary air, is encountered. In these furnaces the refuse is fed through chutes in the arch directly over the fuel bed or, in some cases, through chutes placed near the side walls of the furnace.

When the refuse is principally from kiln dried wood, much of it will burn in suspension, if the height of the furnace is sufficient and the opening is at the top. When the fuel contains considerable moisture, however, it will drop to the surface of the fuel bed, where it is dried quickly and burned.

In the case of side feed stokers of the V-type good results have been obtained by feeding the wood refuse

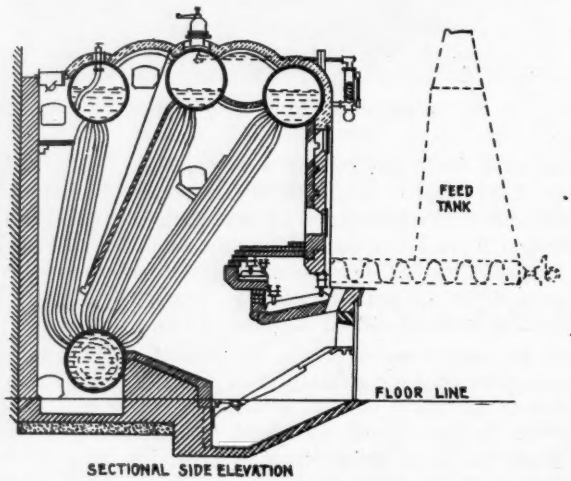


FIG. 3. SCREW CONVEYOR WITH FRICTION DISK DRIVE IS EASY TO REGULATE

through chutes in the arch to the center of the furnace, the coal being fed to the stoker in the usual way from hoppers at the sides of the arch.

In some installations the designing engineer has preferred to burn the coal and wood on separate grates. This is made necessary only when there is insufficient wood for all fuel requirements or where it requires drying to some extent. This arrangement provides flexibility as the boiler can be operated with either wood refuse or coal or a combination of the two fuels. Either a hand fired grate or mechanical stoker may be employed for the burning of the coal and a specially designed furnace and grate are provided for the burning of the wood refuse. Such an arrangement, however, will probably not be considered economical, except where the supply of wood refuse is likely to be intermittent, as the expense of stoker installation would not pay for the investment unless the stoker is used a large per cent of the time. Some plants are designed for the use of oil as a standby fuel in case the wood waste is insufficient at times. This provision does not entail a great deal of additional expense and has many conveniences.

In many plants the engineers prefer to operate one of their boilers on wood refuse alone rather than to use mixed fuel, where the supply of this refuse is not sufficient for the entire plant. This arrangement permits the engineer to design a furnace especially for wood burning. This simplifies the operating conditions considerably and better efficiencies can usually be secured this way than when mixed fuel is used.

Most recent practice would indicate that best results are secured with wood refuse alone when an inclined front feed type of grate or stoker is employed. The inclination of this grate is slightly greater than the repose angle of the fuel itself and the fuel is usually dropped upon stationary grates, coking plate or hearth in front of the fuel bed from chutes in an overhead arch or through the front of the furnace. These chutes are so spaced as to distribute the fuel across the front of the furnace as evenly as possible. With dry fuel much of this is burned in suspension before it reaches the grate. The larger chips and shavings falling to the grate travel towards the ash dump during the process of combustion.

With wet fuel it is essential that the furnace be designed with arches to reflect radiant heat back upon the entering fuel, so as to dry and ignite it in the front of the furnace. When the moisture is 50 per cent or greater coal is burned with the wood to maintain the temperature of the furnace up to the ignition point of the fuel. With front feed inclined grates coal may be fed on one side and wood on the other in the proper proportions to give complete combustion of both fuels.

Requirements for Efficient Combustion

In the burning of any fuel there are three requirements which must be met in order that efficient combustion may be obtained. These are: sufficient furnace temperature first to insure ignition and then to maintain combustion until all gases are burned; second, the air supply must be sufficient to give complete combustion; and, third, the mixture of the air with the gases must be such as to prevent stratification and unburned gases from escaping up the chimney.

While these requirements are simple, they are not always easy to meet and particularly with wood refuse, such as accumulates around woodworking factories. The temperature of the furnace depends upon the net calorific value of the fuel, the rate of combustion, the amount of excess air admitted to the furnace and the amount of heat carried off by radiation to the water in the boiler or to the atmosphere.

In taking up these factors it may be stated that the value of the fuel is beyond the control of the engineer; that is, he is required to burn the refuse of the factory whatever quality it may be. In many plants this fuel contains moisture as high as 60 per cent.

Rate of combustion, which quite commonly reaches 200 lbs. per sq. ft. of grate area, may be governed by the operator, but has its limitations in furnace and grate design which govern the amount of air passing through the fuel bed and its introduction into the furnace. The volume of the combustion space is also a matter of design and is one of the limitations of the rate of combustion. The location of arches that reflect heat for drying and igniting the fuel commonly called "bottling of the heat" also has its effect governing the rate of combustion obtainable in a given furnace.

Excess air is a matter of furnace design and operation.

This, of course, should be held down to a point where complete combustion is secured without the production of carbon monoxide in the flue gases. Sufficient air must, of course, be supplied for combustion but too much is a waste. It is supplied through the grates, fuel chutes and air ports in the furnace wall or bridge walls or through the fire door.

Heat radiated to the boiler is not wasted. It does, however, lower the furnace temperature and may cause incomplete combustion if the temperature gets below the ignition point of the gases. Heat radiated to the atmosphere through the furnace walls or carried up the chimney, due to excess air, is a direct loss and should be prevented as far as possible.

In the burning of wood fuel a grate has three principal functions: first, to hold the fuel while burning; second, to permit air to flow through the fuel bed; and, third, to let the ash drop out of the fuel bed when completely burned. Most recent practice would indicate that for a wood-burning furnace the grate should be of an inclined type. The upper part of the grate receives the fuel from the chutes and acts as a hearth for drying or coking. Inasmuch as the entering fuel is not burning unless it be extremely dry, the air openings in this part of the grate are usually small. As drying takes place, however, this fuel descends by gravity, due to the burning of the fuel in the lower part of the grate, and as it burns it requires more air and grates of a type which will permit large quantities of air to pass through them, such as the step grate, are usually provided. Farther down the grate the ash accumulates and frequently clinkers are formed so that a dump plate near the bridge wall is quite a necessary provision.

Usually a wood-burning furnace is operated on natural or induced draft, as the resistance through the fuel bed is not great and there is, even with a low furnace draft, a tendency for holes to form in the fuel bed. For this reason, some form of rocking grate works well for the lower sections which can be operated to cover holes in the fuel bed.

Air which comes in with the fuel is of value only as a conveyor of the fuel itself and should be kept down to the least possible. When the fuel is fed by means of a blower the quantity naturally is greater than when fed by gravity from a screw conveyor. The air supplied over the fuel bed commonly called "secondary" air is frequently admitted through the fire door or in some cases through tuyeres in the side of the furnace or at the bridge wall. The amount of this secondary air ranges from 0 to 20 per cent of that required for complete combustion. Air admitted through the fire door is at the temperature of the boiler room and must be heated in the furnace up to the kindling point of

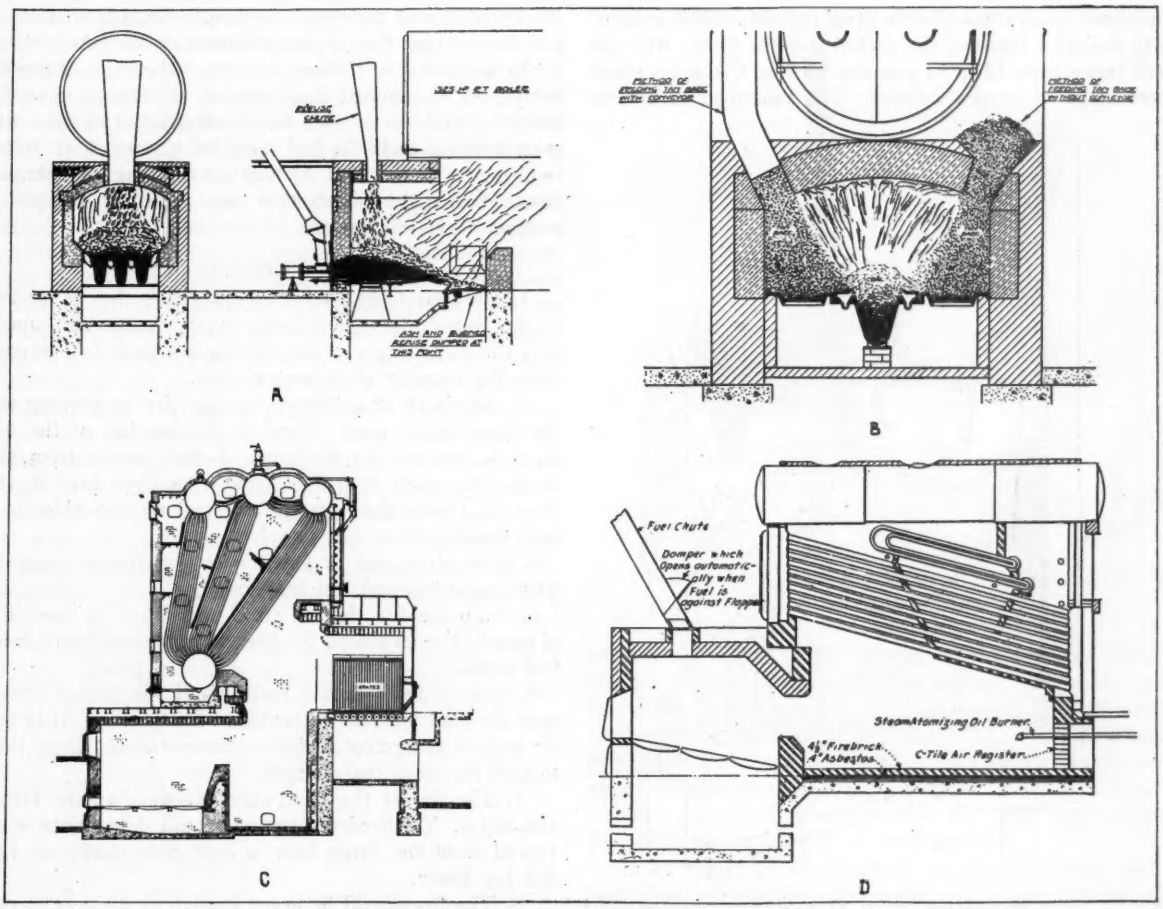


FIG. 4. FURNACES DESIGNED FOR BURNING WOOD WITH OTHER FUELS

A. Wood and coal on underfeed stokers. B. Underfeed stoker and wood-burning furnace. C. V-type stoker arranged for burning coal and tan barks. D. Furnace for wood and oil burning.

the fuel. That supplied through the furnace walls or bridge wall, however, may be preheated before it enters the furnace and, in this way, does not chill the gases with which it comes in contact. Tuyeres in the bridge wall also have the advantage of cooling slag which may collect on the bridge wall and preventing it from fusing into the fire brick of the furnace. It also aids in obtaining a mixture of gases by breaking up the strata of gases leaving the fuel bed. Combustion is, therefore, immediate and with proper equipment the supply can be carefully controlled.

As with the burning of coal, the determination of the correctness of combustion with a wood-burning furnace is indicated by analyses of flue gases and ash. With a properly designed furnace, the carbon dioxide in the flue gas will range from 12 to 15 per cent with no CO and a small percentage of oxygen content. The unburned carbon in

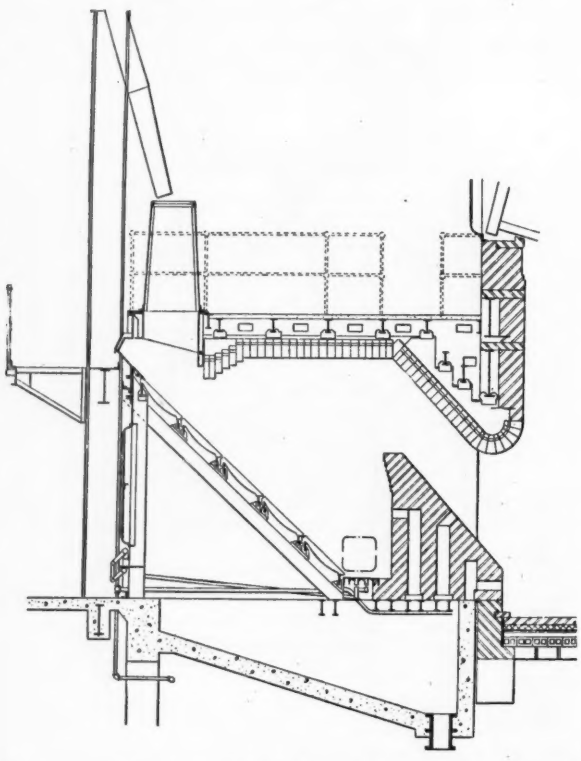


FIG. 5. THE DROP NOSE ARCH IS PROVIDED FOR BURNING WET WOOD WASTE

the ash is usually a small per cent as the fuel is quite porous and permits of close contact with the air passing through the fuel bed.

One of the most common difficulties in the burning of wood fuel is the development of holes in the fuel bed. This may be corrected, to some extent, by giving the proper slope to the grate which should have an inclination somewhat greater than the repose angle of the fuel, thus causing the thickness of the fuel bed at the rear to be greater than at the front of the grate. This same effect may be obtained by rocking sections of the grate though this practice should be avoided as much as possible. In the burning of wood refuse, best results are obtained when the fuel bed is not disturbed except to keep the holes covered.

Furnace proportions to meet combustion requirements vary widely. They depend largely upon the moisture in the fuel. Dry wood refuse burns principally in suspension and requires large furnace volume.

In one plant 7 cu. ft. of combustion space per rated boiler horsepower is provided.

Wet fuels require less volume of furnace, from 3 to 5 cu. ft. per rated boiler horsepower, and less exposure to the heating surface of the boiler. The provision of arches to reflect the heat on the fuel for drying and ignition aid greatly in maintaining the proper temperature and mixing walls to break up the stratification of the gases are of service in obtaining better combustion. Temperatures range between 1500 deg. for wet fuel to 2800 or 3000 deg. for dry fuel and the ratio of grate to heating surface of 1 to 3.1 has been found quite satisfactory for wet redwood.

In a discussion of wood burning before the American Society of Mechanical Engineers A. A. Straub gave the following hints to firemen for burning hog fuel on a flat grate with flat arch, the fuel being fed through four chutes resulting in a fuel bed of four overlapping cone-shaped piles. With slight modification these rules may be applied to other forms of grates.

Hints for Firing Hog Fuel

1. Keep pit doors open at all times on boilers in service.
2. Control the steam pressure and main air supply with the boiler damper. Supply the necessary fuel to generate the quantity of steam required.
3. Admit air at all times over the fire by keeping the fire doors partly open. Regulate the opening of the fire doors to prevent the discharge of dark smoke from the stack. The stack should be clear or a light haze should leave it. Planer shavings and dry fuel require wider firedoor opening than wet, fine fuel.
4. Fire often and in small quantities rather than in large quantities and less frequently.
5. Keep the fire thin in front and heavy in rear; top of rear fuel cones should be closer to arch than top of front fuel cones.
6. Fire in front should reach about four to six inches over the dead plate at the center of firing doors. It is better to have the grates slightly uncovered at the front than to have too much fuel charged.
7. The fire at the front should always appear bright and active. The firedoor opening should show bright when viewed from the firing floor, a dark door shows the fuel bed too heavy.
8. The fire should be heavy enough in the rear to prevent vicious flame coming through at the bridgewall.
9. With coarse, dry fuel the fire should slope at rear to slightly below the top of the bridgewall. With wet fuel it should be somewhat thinner. With fine, wet fuel the fire at the rear should slop to about half-way up the bridgewall.
10. Fire in the rear should be carried heavier for coarse and dry fuels and thinner for fine, wet fuels.
11. At no time entirely close the ashpit or firing doors on a boiler in service; use the boiler damper for main control of air supply.

After cleaning, a boiler should be thoroughly flushed out, as pieces of floating scale will otherwise settle in the tubes and cause tube burnouts.

One of the secrets of the successful operation of any oil burning system is keeping the system clean.

Producing and Controlling Combustion Air

DAMPER REGULATORS, COMBUSTION CONTROL SYSTEMS, FORCED AND INDUCED DRAFT FANS AND REGULATION OF SECONDARY AIR

GENERAL REQUIREMENTS for draft necessary in various methods of burning fuel, as used in the modern power plant, have been discussed in some detail in the preceding pages. It is the purpose of this article to discuss briefly the operation of some of the equipment used in obtaining and regulating draft. In a great many plants various types of fans, both forced draft and induced draft, are used. Dampers are often operated by automatic devices of various kinds and there are now coming into use several methods of combustion control in which automatic devices regulate not only the dampers and speed of the various fans, but also the amount of coal fed to the furnace either by stokers, pulverized fuel feeders, oil burners or other mechanical forcing devices.

One of the early steps towards the use of mechanical controls in combustion was the development of the damper regulator. This controls the position of the stack damper, or, in the case of a battery of boilers, the breeching dampers as in Fig. 1. The next step in mechanical control was the use of regulators for adjusting the speed of induced fan and stoker engine or motor, according to the particular conditions of combustion. The furnace pressure regulator developed next and finally various more complicated arrangements of combustion control equipment have been worked out. Regulators that depend for their action on change in steam pressure may use a diaphragm, a spring, a Bourdon tube, or a mercury column, which in turn operates some sort of a valve mechanism to admit water on pressure to a cylinder or a piston. The movement of this piston then furnishes the motive power for opening and

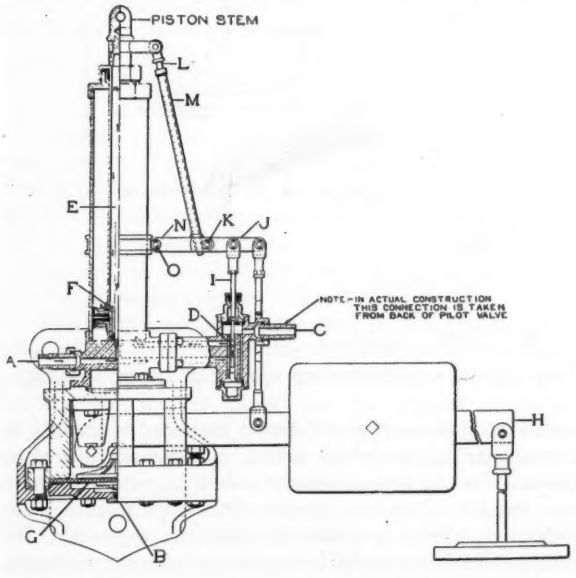


FIG. 1. TYPICAL HIGH PRESSURE DAMPER REGULATOR

closing the damper or for the operation of a chronometer valve to regulate steam supply to fan or stoker engines, or to vary motor speeds. The various regulators differ in the methods used to counter-balance the regulator, to secure adjustment for various pressure ranges and to conform to the ideas of the designers.

In one type of regulator a mercury column is utilized. In response to changes in steam flow and steam pressure, the mercury rises and falls and a float transmits these changes to valve gear operating a four-way hydraulic valve. This type of regulator is often used as a secondary unit, operated by a master controller.

In the regulator shown in Fig. 1 a diaphragm operates when the steam pressure under diaphragm G is sufficient to raise weighted lever H, pilot valve stem I is raised and

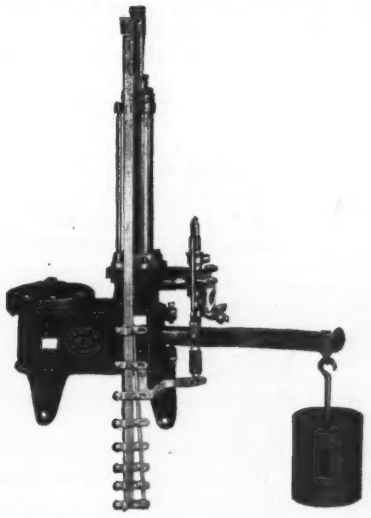


FIG. 2. VARIABLE STEP ACTION FAN ENGINE OR DAMPER REGULATOR

water is admitted to the bottom of the cylinder which forces the piston F up and closes the boiler damper. As the piston travels upward the compensating attachment lowers pilot valve stem I and shuts off the water pressure, which arrests the upward travel of the piston and the closing of the damper until there is a further increase in steam pressure, this increase raises lever H higher and causes the piston to continue its upward travel.

In another type of regulator, an arrangement is used that does not require counter-weights. The motion of the plunger is communicated to the lever of the damper by a yoke and chain, on which is hung only enough weight to overhaul the plunger. The latter is operated by steam direct from the boiler and its admission is controlled by a sensitive metallic diaphragm, which operates the valve within a range of 1 lb. pressure.

In the step action regulator shown in Fig. 2 the compensating effect is not applied uniformly to produce uniform control of the plunger from uniform variations of pressure acting on the diaphragm, but is applied abruptly at definite pre-determined points in the operation of the plunger to cause a positive stopping of the plunger and a change in pressure setting which will prevent the plunger from being operated again until a definite change in load is indicated. The scale beam moved by variations in pressure acting on the diaphragm, moves the pilot valve to a pressure position and imparts motion to the plunger. This in turn gives motion to the step compensator, causing the roll to engage a higher or a lower step position, which moves the valve back to its neutral position, stopping the

plunger. At the same time, an increase or decrease in the tension of the spring changes the pressure setting of the regulator, causing a greater or less weight at each cut-off step according to the angularity of the adjustment of the cutoff wedge.

Draft Over Fire Actuates One Type of Regulator

If the draft over the fire is used as a means of actuating regulator, a gasometer is sometimes used to create the movement necessary to open the control valve or damper. This is done in the regulators shown in Fig. 3. Changes in furnace draft are transmitted to the gasometer, an increase in vacuum causing the inverted bell to descend and a decrease causing it to rise. This rise or fall operates the four-way valve and opens the proper port on the hydraulic cylinder, the piston of which actuates the damper

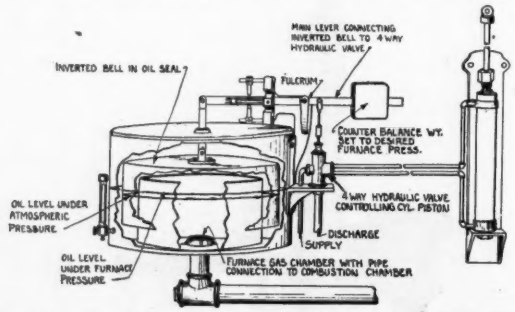

MAIN LEVER CONNECTING INVERTED BELL TO 4 WAY HYDRAULIC VALVE
INVERTED BELL IN OIL SEAL
FULCRUM
COUNTER BALANCE WT. SET TO DESIRED FURNACE PRESS.
4 WAY HYDRAULIC VALVE CONTROLLING CYL. PISTON
OIL LEVEL UNDER ATMOSPHERIC PRESSURE
DISCHARGE
SUPPLY
OIL LEVEL UNDER FURNACE PRESSURE
FURNACE GAS CHAMBER WITH PIPE CONNECTION TO COMBUSTION CHAMBER

FIG. 3. REGULATOR OPERATED BY DRAFT OVER THE FIRE

until the draft has been restored to a pre-determined intensity. Then the bell moves back to the balanced position and holds the cylinder piston and the damper at rest. A change as small as 0.01 in. operates the regulator.

The gasometer principle is used in the other types of regulators, the method of transmitting its movement to the damper differing in mechanical arrangement.

It is customary to install draft regulators of the various types on the wall of the engine room or turbine room, if this wall adjoins the boiler room, and to lead a chain from the top of the actuating mechanism through a pulley to a unit to be controlled in the boiler room. If a master controller is used with auxiliary controls for several boilers, arrangement can be varied to suit the particular conditions of each plant. Generally speaking, it is not considered good practice to connect damper regulators to main dampers, since main flues are usually laid out for extra boiler settings, which, in many cases, were never set. The main dampers, therefore, seldom bear any relation to the volume being generated in the various boiler furnaces that are on the line.

On the other hand, the size of an uptake damper of an individual boiler bears a fairly close relation to the volume of gas being generated in the furnaces of that boiler. For that reason, many engineers consider it advisable to connect the regulator to the uptake dampers, instead of to the main dampers. Where there is more than one boiler, it has been found good practice to connect all uptake dampers together with a line shaft and to operate all boilers with one regulator.

When the regulators are connected to throttling valves for the control of steam driven units, it is desirable to use a valve with an adjustable orifice, or a valve whose size will bear a definite relation to the boiler load.

The hydraulically operated regulator is the most common type of regulator in use, although the steam actuated and motor driven regulators are used to some extent, the latter being adapted to control of variable speed motor driven forced and induced draft fans. It is not desirable to install dial switches or drum controllers in connection with regulators that operate with hydraulic pressure. There is always some danger that small pipes will be broken, which might cause a spraying of the electric apparatus.

The elements of the motor operated regulator are the same as those of the hydraulic regulator, except that a pilot switch takes the place of a pilot valve and an electric motor takes the place of a fluid pressure motor; otherwise, these regulators are the same.

Combustion Control Systems

It is possible to control by mechanical means many of the factors entering into the process of combustion in a boiler furnace and to adjust the relations of these factors with one another. Frequently, one type of regulator may be used for controlling the draft fan by steam pressure and another type of regulator may be used for controlling the dampers by means of over-fire draft. Views differ on the arrangement of the control equipment and several organizations are either building the equipment for the entire

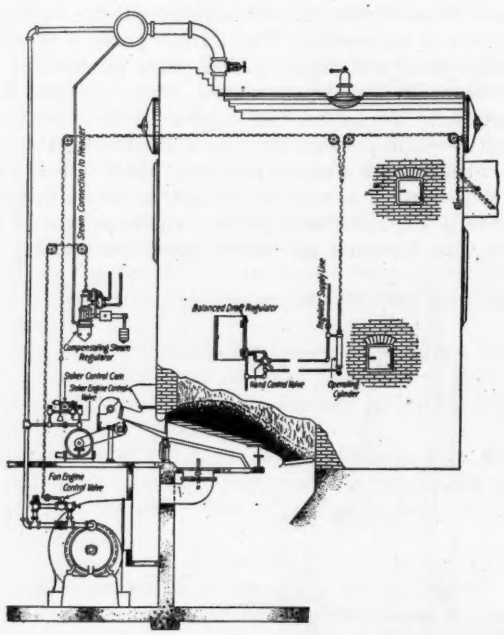


FIG. 4. ARRANGEMENT OF BALANCED DRAFT SYSTEM

system or have assembled different makes of apparatus in a particular scheme, which is then installed as the control system. In one type of control system the steam pressure type regulator and the over-fire draft type regulator are connected to form a system of automatic regulation, the arrangement being varied in accordance with the particular conditions of operation.

In the balanced draft system of combustion control the fundamental basis is a determination by experiment of the most efficient suction for the given boiler. When this determination is made, the problem is reduced to providing any effective means of maintaining the required suction under any and all conditions. In this system, therefore, the overfire draft is given the most important functions in the control scheme.

Figure 4 gives an idea of the general arrangement of this type of control. The cylinder of the compensated regulator operates a valve in the steam line to the fan. The piping is so arranged that enough steam to hold the fan at minimum speed goes directly to the fan, without passing through the valve, while the steam for increasing speed passes through the regulating valve. The regulator can also be arranged for various forms of electric control or can be made to vary the amount of air from a constant-speed fan or from a reservoir by means of air-gate dampers in the air duct.

Operation of the breeching damper and variation in speed of the stoker drive are obtained by the use of a

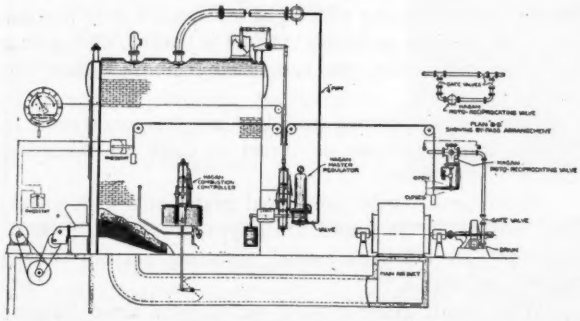


FIG. 5. COMPENSATED DRAFT CONTROL SYSTEM

furnace pressure regulator which is mounted on the side wall of the boiler and connected to the furnace chamber above the fire by means of a draft tube passing through the wall.

Figure 5 shows a diagrammatic layout of another combustion control scheme. It consists of a master regulator, operated by steam pressure, which controls the flue damper, the stoker drive and the speed of the forced draft fan. In addition there is a combination controller which is used to operate the blast gate in the air duct where more than one boiler is supplied with air from the forced draft fan.

Another automatic control system employs two separate controls. First, a master control by means of which change of the output of all the boilers is governed according to the steam pressure, and, second, an individual control for each boiler by means of which large excess air for combustion is automatically maintained at a definite amount according to the boiler rating.

The master control is operated by the station steam pressure. When the pressure drops below the standard, impulse is given to all the boilers which increases both the coal feed and air supply and the opposite occurs for an increase in pressure. When changing rating, the equipment for the control increases the air supply faster and decreases it slower than the coal supply, so that an excess of air is always provided during a change in rating.

Figure 6 shows a regulator for varying the speed of a brush shifting motor driving a forced draft fan. This regulator is one used in the combustion control system employing balanced mechanical regulation. In this system each unit is controlled by a separate regulator on each machine, actuated by a master controller for the whole system. In the master control of steam, pressure is balanced against the master control air pressure which maintains a ratio between the amount of fuel fed to the furnace and the amount of air for combustion.

Fans used for the production of artificial draft in modern furnace installations may be classified under two general types, i.e., centrifugal type fans and propeller type fans, depending upon whether the air is drawn in axially from one or both directions and discharged tangentially, or whether the air is discharged axially. In the latter case, the blades are of the propeller type, hence the name.

Pressure Systems

Forced-draft pressure systems are of two kinds, those in which each fan is connected to its individual boiler by a separate duct and those in which a number of fans are connected into a common system of ducts, supplying air to one or more boilers. Practice in this respect is divided. Boiler units of 800 hp. and larger, equipped with forced draft stokers, are suitably served by individual fans.

Older types of fans were not built sufficiently heavy for operation at the high speeds necessary to produce the high pressures demanded, consequently new types were developed capable of being operated at high speeds. The method of driving also changed from the use of the slow-speed reciprocating engine to high-speed turbines and electric motors. Of course, the slow-speed fan is not limited

FIG. 6. DIAPHRAGM REGULATOR CHANGES SPEED OF BRUSH SHIFTING FAN MOTOR AT COMMAND OF MASTER CONTROLLER

to slow speed drives for, by means of suitable reduction gears, any type of drive may be used.

To select a fan of proper size to meet the required conditions is most suitably accomplished through the use of capacity tables furnished by manufacturers. Knowing the outlet velocity of the air in feet per minute and the static pressure, these tables will give the correct size of any fan in horsepower capacity. The nearest commercial size which will meet the volume and static pressure requirements should be selected.

Requirements to be met by induced-draft fans, or exhausters, differ materially from the requirements for forced draft practice. The conditions under which such fans are required to operate are much more severe than the conditions imposed by forced-draft systems and to decide upon

a satisfactory induced-draft system requires considerable experience and common sense.

Induced draft has a number of advantages over forced draft, but, except in the case of small installations having stokers with only a small draft loss through the grates, should not be used alone, otherwise the fan capacity becomes large and the installation expensive.

Types of Construction

Since the induced draft fan handles hot gases, it must be capable of handling a much larger volume of gas than the forced draft fan. For usual installations the hot gases at the induced draft fan have a density only half that of the air at the forced draft fan, consequently their volume is twice as great. To deliver this will, of course, require twice the horsepower.

Induced-draft fans have usually been of the narrow multi-bladed type, this being necessitated by the speeds at which they run, as most installations are direct connected to the driving motor. The use of fans of this type, however, involves certain difficulties due to the space between the blades clogging up. Without question, the steel plate or paddle wheel type of fan of proper proportions is by far the most suitable of all for this work.

Special Construction for Hot Gases

In order to obviate bearing troubles and to provide an unobstructed inlet passage, most fans for induced-draft work are of the overhung type, that is, both bearings are on one side of the fan and outside of the path of hot gases. Water-cooled bearings are sometimes provided to eliminate overheating, caused by heat from the gases being conducted along the shaft to the bearings.

What has been said in regard to the method of drive for forced-draft fans applies more or less to induced-draft fans. Whether steam or electric drive is to be used depends upon existing local conditions. Alternating current motors of the wound rotor induction type, hand controlled and direct connected to the fans seem to be the preferred method of drive at the present time.

Furnace blowers are of two general types; steam jet and mechanical. Steam jet blowers possess the advantage of being simple to install and operate and low in first cost, but steam consumption is likely to be excessive. For this reason, their most common use is in plants requiring forced draft only for short periods during the day.

Mechanical furnace blowers are built directly into the walls of the furnace, therefore require but little space; they are compact and easily accessible for inspection and cleaning. Practically all such blowers employ the propeller type fan largely for the reason that changes in discharge pressure due to variations in fuel bed resistance have but little effect on the quantity of air delivered. This gives a certain advantage in design because it is almost impossible to determine beforehand just what the fuel bed resistance will be. Any change in demand for air, brought about by variation in the steam demand, may be met by varying the propeller speed. Speed variations may be effected by a regulator actuated by change in boiler pressure or in over-fire draft.

In the operation of chain grate stokers, divided wind box control is often used. In this system air for each stoker is brought in from a common air duct supply by the forced-draft fans and is then led into a divided wind box between the runs of the stoker to give zone control of combustion. To do this, dampers are placed at the entrance to each stoker compartment which are regulated by the fireman, in accordance with the fuel bed conditions as he observes them. Naturally, if he observes a hole appearing in the fire over a certain zone he must decrease the air supply somewhat until the stoker has fed more coal over that zone and then he must increase the air supply back to normal to take care of the normal amount of fuel being fed.

Considerable work is being done at present on automatic devices to control the various dampers in a divided wind box, but up to the present time such automatic equipment has not been placed on the market. This divided wind box control for chain grate stokers is considered an advantage when running with light loads, since it is possible to reduce the area on which the fuel is burned, thus giving a higher combustion rate and usually giving higher efficiency.

Practice in supplying secondary air for combustion in various cases is almost as varied as there are manufacturers of equipment.

Theoretically, with hand fired grates and with underfeed stokers of the forced draft type, there should be no secondary air although special operating conditions may make it advisable.

With chain grate stokers particularly those burning anthracite, overgrate air at the back of the furnace with special design of mixing arches in many cases has proved of advantage. This air is used to reduce a CO condition which frequently exists and also it is used as the mechanical means of blowing the fines of fuel from the back end of the grate forward into the burning zone. Overgrate air is used sometimes with perforated blocks to prevent clinkers. All of these matters, however, are controls of operating variables and, we believe, as such must be manual.

In some pulverized fuel systems, the air carrying the coal is small and large amounts of auxiliary or secondary air must be admitted. This can be accomplished in two ways—first by operating with constant draft and automatic regulation of the air openings; the second is to provide fixed openings and automatically change the draft.

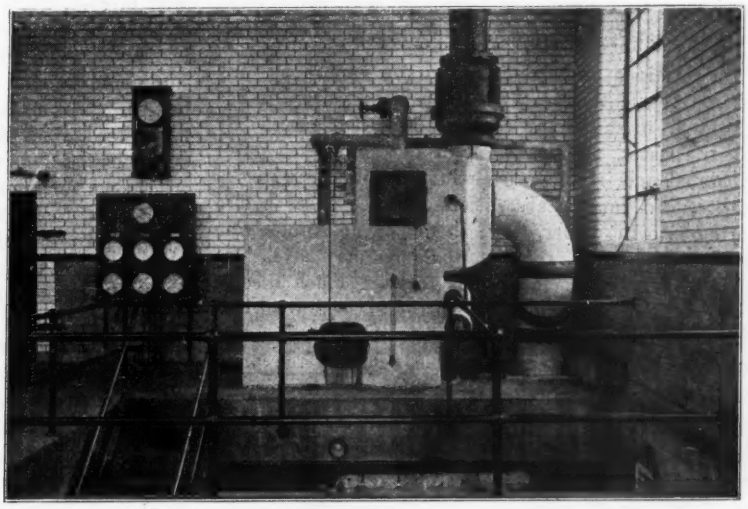
In other systems the carrying air constitutes nearly all of the air needed for combustion. Here the regulation is simpler as the furnace draft can range between very narrow limits; and, as a practical operating matter, a good average fixed set of constant draft is probably closer than most attempts to get a correct point with variable draft.

Another feature of the powdered coal is that manufacturers are generally now asking for an excess of air during load change periods. That is on ascending loads the air for the new rating should be fed to the furnace before the coal; and on descending loads the coal feed should be reduced before the air is reduced. This condition can readily be handled by automatic equipment.

In the case of oil fuel, here again there are two systems. Where forced draft and the register type of burner is used, the handling of the regulation is exactly similar to underfeed stoker practice. Where natural draft is used variable draft is required. Here it is found that the furnace pressure regulator gives excellent results when set to a good average draft. This is on the principle that a satisfactory constant draft, properly maintained, gives better efficiency than the theoretically correct draft which cannot be maintained by hand with any degree of accuracy.

Feed Water Systems

METHODS OF PURIFICATION, HOT AND COLD CHEMICAL TREATMENT, EVAPORATION, DEAERATION, RECIRCULATION AND FILTERING. METHODS OF HEATING. BOILER FEEDING ARRANGEMENTS, PUMPS, METHODS OF CONTROL, ECONOMIZER OPERATION



AN ESSENTIAL REQUIREMENT in boiler plant operation, particularly in those plants where high pressures and extremely high ratings are used, is a source of pure water for boiler feeding purposes. If impure water is used, it is obvious that, as the water evaporates and is removed from the boiler in the form of steam, the impurities will remain and will collect at the bottom as a sludge or, depending upon their nature, will form a scale on the interior surfaces. The larger the boiler and the higher the rate of steaming, the greater is the need for pure boiler water.

Now, pure water, while easy enough to produce artificially, is extremely rare in nature. Rain water as it falls from the clouds is comparatively pure, carrying nothing in solution except a minute quantity of carbon dioxide but, as soon as it touches the ground, it begins to dissolve the materials with which it comes in contact and becomes impure, using the term in its broadest sense.

The quantity and quality of the impurities in any source of water supply other than rainfall depend entirely on the character of the ground or rock stratum through which it passes. In addition to the organic and inorganic constituents held in suspension and in solution in raw water, there may also be present certain dissolved gases, such as oxygen, carbon dioxide and sometimes hydrogen sulphide. These gases, if allowed to enter the boiler, are claimed to be the cause of pitting and corrosion of the steel heating surfaces. When water carries sufficient salts of calcium and magnesium, it is said to be hard and, if used in a boiler, will result in the formation of scale. In order, therefore, that operating difficulties due to the formation of scale or the liberation of corrosive gases in the boiler may be eliminated, it has become common practice, except in small plants where a comparatively pure source of water is available, to subject the water to certain chemical, mechanical or thermal treatment before or after its introduction into the boiler. Sometimes this treatment consists merely in removing suspended solids; in other cases, the removal or neutralization of dissolved matter—the procedure in each case depending upon local conditions.

SCREENS AND STRAINERS

Clarification of water by filtration is simple and is usually accomplished by passing the water through a series of screens or layers of sand and gravel. The downflow type of filter, using sand or granulated quartz as filtering mediums, is widely used and has proved highly effective. In certain cases, particularly where the water is to be used for drinking purposes, filtration through the sand beds is preceded by coagulation and sometimes by sedimentation.

When the water is higher than usual in suspended matter, it should not be delivered direct to the filter bed, because such water will quickly foul the filter bed and make frequent backwashing necessary. Such waters should settle from 1 to 4 hr. before delivery to the filters.

Operation of the sand type of filter should give little trouble, provided it is of sufficient capacity to supply the needs of the plant and if proper attention is given to backwashing. When water flows through a filter, the solids are retained on the filter bed, where they in no way interfere with perfect filtration but, on the contrary, cause increased frictional resistance and afford a finer screening than when the filter was first placed in service. In fact, a filter is most effective just as its capacity begins to decrease. When the solids accumulate on the surface of the bed to such an extent that the frictional resistance through the bed becomes excessive, it is generally found desirable to remove them by backwashing. This consists in passing water upward through the filter at a rapid rate, causing a boiling of the sand and carrying away the impurities.

It is not necessary, except in unusual instances, to filter water before chemical treatment but it is common practice to pass the water through a filter after it has been treated chemically in order to remove the last traces of suspended matter.

In small installations, a simpler form of filter is often used, consisting merely of a compartment filled with bags of excelsior, charcoal, loofa sponges or other filtering material. This type of filter is largely used in marine practice. The disadvantage, of course, is in the difficulty of

cleaning the filtering material. This, as a rule, must be removed from its container and replaced with new.

Purification by Preheating

To a certain extent, boiler feed water can be purified by boiling it violently under atmospheric pressure. As has been stated, most waters contain dissolved gases. By boiling the water, practically all of these dissolved gases are liberated and, if these are removed and the water is not exposed to further absorption of these gases before delivering into the boiler, there should be no trouble due to any damaging effects the dissolved gases may have. The question of internal corrosion has received much discussion and opinion is divided. If corrosion is due to dissolved gases in the feed water, boiling the water in this manner should eliminate the trouble. This is the principle employed in deaeration, to be discussed later.

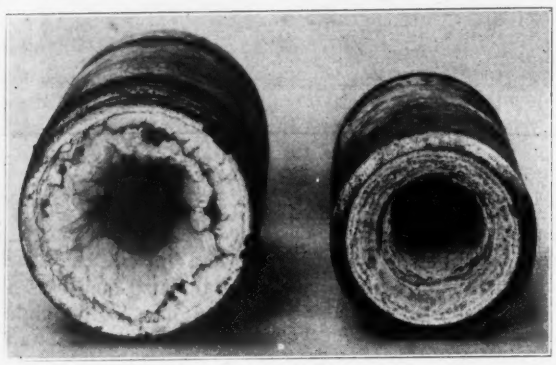


FIG. 1. TWO EXTREME EXAMPLES OF SCALE DEPOSITS IN WATER LINES

Another effect of heating the water is a reduction in hardness. The bicarbonates of calcium and magnesium, which constitute the chief source of hardness in most waters, are broken up into carbonates and CO_2 when the water is heated to the boiling point. The calcium carbonate is practically insoluble in the hot water and is precipitated as a solid but the magnesium carbonate is only partly precipitated, as it is slightly soluble. While calcium carbonate is more soluble in hot water than in cold water, the difference is slight and the large part of the hardness due to the presence of the bicarbonates may be removed in this manner.

It is thus evident that the ordinary open type of feed water heater, using exhaust steam, is to a certain extent a water purifier. As a rule, however, these heaters are not provided with a means for removing liberated gases and are not of sufficient capacity to permit the water to remain long enough for the precipitation of solid matter.

Chemical Treatment

In most boiler plants some form of chemical treatment is used to produce feed-water of the desired quality. Two basic processes are available for this purpose—the precipitation process and the zeolite process. The former consists in the introduction of certain reagents which precipitate the scale-forming impurities so that they may be removed from the water before delivering it to the boiler. The zeolite process makes use of certain insoluble hydrous silicates called zeolites, which have the property of exchanging their sodium content for the calcium and magnesium constituents of the water.

Among the precipitation types of softeners, the lime-soda process, using lime and soda to effect precipitation, is perhaps the most common and has proved satisfactory in many cases. This process may be further classified according to whether it makes use of hot or cold water. The hot process is usually used in the treatment of water for boiler feed, since the chemical reactions are greatly accelerated by heat and the equipment occupies a much smaller space than for the cold process.

Both of the processes referred to treat the water before it enters the boiler. Where the chemicals are introduced directly into the boiler, the process is designated as treatment by means of boiler compound. Boiler compound of various kinds have been manufactured for years and while some of these possess worth-while qualities, it stands to reason that no one boiler compound can be a panacea for all boiler troubles. Where the ingredients in the boiler compound are based upon chemical analysis of the feed water to be treated, a good boiler compound is often highly satisfactory and in such cases it is, no doubt, the cheapest method of water treatment.

The most common internal treatment consists in the use of lime and soda ash, a treatment often recommended by boiler insurance companies and boiler manufacturers. Barium hydrate and trisodium-phosphate are also used successfully under certain conditions. Where it is deemed advisable to use boiler compounds, it is well to know what these compounds consist of, as many of these products sold under trade names are of unknown and mysterious composition and may actually be of a dangerous nature. Boiler compounds have been used with considerable success for many years in the United States Navy. The standard Navy compound consists of 76 per cent of anhydrous sodium carbonate (Na_2CO_3), 10 per cent trisodium phosphate ($Na_2PO_4 12 H_2O$), 1 per cent of starch and sufficient clutch or dry extract of hemlock, oak or chestnut bark to yield 2 per cent of tannic acid. The remainder consists of water.

Boiler compounds which have been found most satisfactory are those which not only effect the precipitation of the scale-forming impurities, but which also render the precipitated material non-adherent by mechanical action.

Hot Process Lime-Soda Softening

The continuous hot process lime-soda softener consists of a chemical mixing vat, a proportioner for maintaining the correct ration of chemicals to water, a heater for heating the incoming raw water, a sedimentation or settling tank in which actual precipitation takes place and a filter for eliminating the last traces of suspended matter from the treated water.

In a system of this kind, the raw water is fed into the heater on top of the sedimentation tank where its temperature is raised to about 212 deg. This is an open-type heater, so most of the dissolved gases are liberated by this process. The heated water is then mixed with the chemical solution, which has previously been prepared in the chemical mixing tank, and is admitted directly into the sedimentation chamber below. This chamber has ample capacity to insure complete chemical reaction and the subsequent settling of the precipitated particles into the sludge cone from which the sludge is easily removed. Near the bottom of the sedimentation tank the water enters an uptake funnel from which it is drawn at the upper end.

An apparatus of this type is automatic in its action and while it requires little attention, the little it *does* require *must* be given it. The essential requirements may be listed as follows:

1. Maintain a sufficient supply of exhaust steam to keep the temperature above 205 deg. F. at all times as the chemical reaction is greatly accelerated by heat. Where sufficient exhaust steam is not available, live steam must be admitted through pressure-reducing valves.

2. Chemicals must be charged into the tank regularly, the correct amount of each kind introduced being determined by the titration test. If the correct amounts are not supplied, the water will be undertreated or overtreated.

3. The chemical proportioner must be inspected daily to see that it is working properly.

4. The sedimentation tank must be blown down regularly to prevent it from filling up with sludge.

5. The filter (if installed) must be backwashed at regular intervals to insure ample head on the boiler feed pumps.

6. The boilers must be blown down regularly and sufficiently; otherwise, soluble salts will accumulate and cause foaming or priming.

7. Avoid running the equipment at a higher capacity than that for which it was designed.

Zeolite Treatment

Softening by the zeolite method may be explained as an exchange process. The normal zeolite contains sodium in such condition that it can be replaced by the calcium and magnesium in the water. The sodium zeolite carries a definite quantity of the replacement sodium and when water containing calcium and magnesium passes through a bed of the zeolite, an equivalent quantity of the calcium and magnesium exchanges for the sodium forming calcium or magnesium zeolite while the salts of the sodium remain in the softened water. The complete exchange of the sodium for calcium and magnesium causes the zeolite to become exhausted and regeneration is required to restore the sodium content.

Regeneration is accomplished by adding to the zeolite a solution of a salt which carries a large sodium content. The salt most easily secured is ordinary table salt, sodium chloride. When the salt solution is passed through the exhausted zeolite, the sodium from the salt replaces the calcium and magnesium in the zeolite, reviving and converting the mineral to its original state. The regenerated zeolite is then again in condition to exchange the sodium for the calcium and magnesium present in water. This process of exchange and regeneration may be carried on for an indefinite period without injury to the zeolite.

Two distinct kinds of zeolite softeners are manufactured in America—the natural and the synthetic. Natural zeolites are found in several places in this country but only a few deposits have been worked. Zeolite material, as mined, is not entirely satisfactory for water softening and requires some treatment with soda before it is finally dried, crushed, graded and ready for use.

Although the several types of zeolite water softeners vary from one another in respect to operating details, the principle is the same in all of them and all function in the same manner. It is usual to first pass the water to be so softened by the zeolite process through a filter, as suspended matter in the water tends to reduce the efficiency of the softening material. The turbid matter, it seems, coats over the grains of the softening substance and prevents the exchange action.

Softening water, of course, regardless of what process is used, will not change the properties of the water other than eliminating the hardness forming constituents. Any action due to other properties must be taken care of separately and the water softening method cannot be blamed if this is not done.

In connection with zeolite processes the theory has been advanced that sodium hydroxide formed in the boiler salines from sodium carbonate may, in the absence of sulphates, by some corrosive action, accelerate the formation of cracks in the internally stressed material of riveted seams. It has been proposed by those advancing this theory to maintain a ratio of sodium sulphate to sodium hydroxide in the boiler salines that is greater than 1 in the hope that it may be beneficial to internally stressed metal.

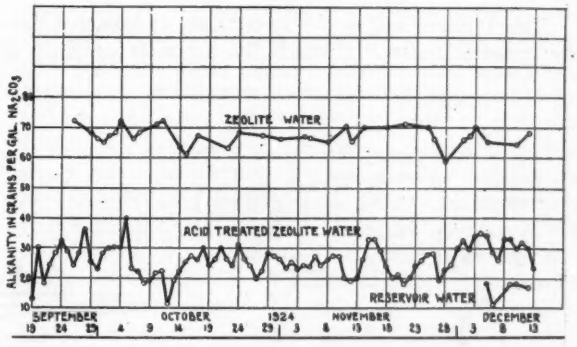


FIG. 2. A 4-MO. OPERATING LOG SHOWING THE EFFECT OF ADDING ACID TO THE ZEOLITE-TREATED WATER AT CALUMET STATION

While the correctness of this theory has been by no means proved, certain manufacturers of zeolite equipment, in order to serve boiler users who desire to increase the sulphate hydroxide ratio of their water supply, have developed apparatus by which the result can easily be accomplished. These manufacturers, in developing this equipment, do not as a rule subscribe to the ratio theory. The usual method used in establishing the desired ratio consists in adding acid to the feed water makeup. A system of this type has been installed at the Calumet Station of the Commonwealth Edison Co., where a two per cent solution of commercial sulphuric acid is used. In order to obtain the desired sulphate-causticity ratio in the boiler water, it has been found that the acid treatment requires that the alkalinity of the zeolite treated water be reduced from 7 grains to 2.5 grains per gallon, as is shown in Fig. 2, which is the actual operating log, as it appeared in the report of the Prime Movers Committee of the N. E. L. A. in July, 1925.

In the acid treatment of carbonate waters, carbon dioxide is liberated As this is considered to be somewhat of an undesirable condition, the mixing funnel in the Calumet installation is provided with an air agitator, so as to effect the removal of the CO_2.

Use of evaporators in central stations and in industrial power plants is of comparatively recent origin. For years, this type of equipment was used aboard ship where no other source of fresh water was available but, because of its

cost, no applications of this principle of feed water purification were made on land.

At the present time, however, evaporators are being used to a wide extent on land, particularly in the central station field. While distillation of the feed water by means of evaporators in stationary plants may not be the most economical method of treatment, it is, without doubt, the only method whereby an absolutely pure water can be obtained. Whether or not an absolutely pure water is desired is another question and will have to be answered largely from a study of local conditions. In many cases the increased cost of evaporation will be more than offset by the decrease in operating and maintenance costs resulting from the use of absolutely pure water.

Types of Evaporators

Two types of evaporator systems are in common use: the pressure system, in which the steam is supplied at a pressure considerably above that of the atmosphere, and the vacuum system, in which the pressure is at or below atmospheric. Another way of classifying evaporators is, as low- or high-heat-level systems. In the low-heat-level system, evaporation takes place at low temperature and corresponding pressure and in the high-heat-level type, evaporation takes place at a high temperature and corresponding pressure. The former usually exhausts into an open heater at a pressure slightly above atmospheric, while the latter exhausts into a special heater or surface condenser through which the feed water passes after leaving the main open heater. With such an arrangment the temperature of the vapor is certain to be well above 212 deg. and its pressure well above atmospheric.

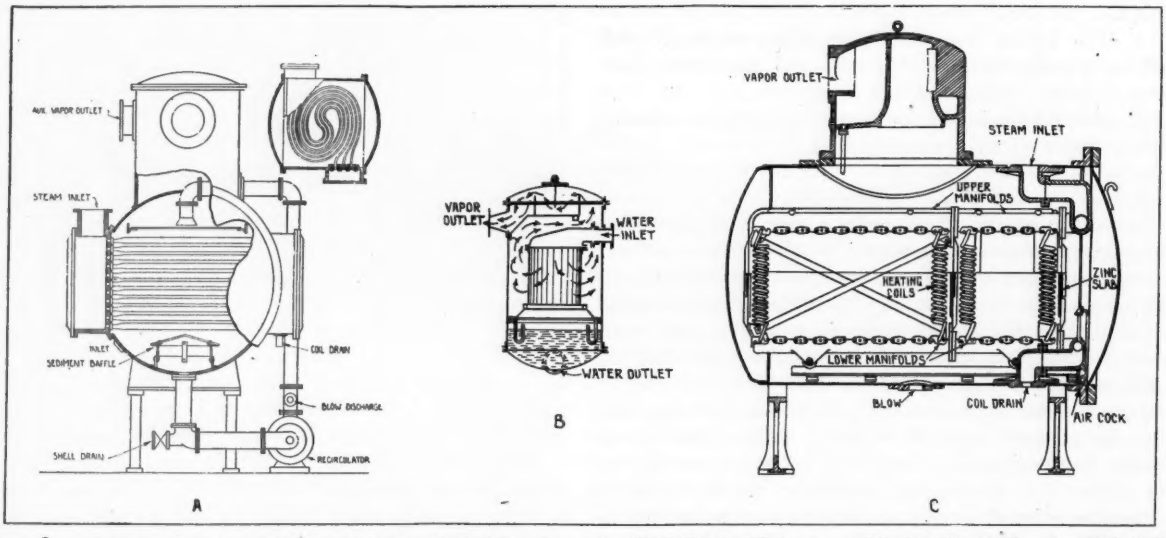


FIG. 3. THREE TYPES OF EVAPORATORS IN COMMON USE. A. THE FILM TYPE. B. THE FLASH TYPE. C. THE SUBMERGED TYPE

Methods of Evaporation

Evaporation of the water may take place in three ways. In the film type, a thin film of water passes over the surface of pipes filled with steam. In the flash type, the vapor flashes from a water injected into a chamber under a partial vacuum, while in the submerged type evaporator, evaporation occurs in much the same way as in an ordinary fire-tube boiler, except that in place of burning gases passing through the tubes we have steam.

Depending upon operating conditions in the plant, a single evaporator may be used or two or more evaporators used in series, the arrangements being called single, double or multiple effect. In the single effect, the vapor driven off from the water is led directly to a condenser, the condensate being delivered to the hot well. This condenser may be that serving the main unit but is usually a separate apparatus using condensate as a condensing medium.

Double and multiple effect arrangements differ from the single effect in that the vapor from the first effect is condensed in the second effect and in condensing evaporates the water in the second effect; vapor from the second effect goes to the third effect and so on to the last effect, the vapor from which goes to the condenser. All condensate goes to the hotwell.

As far as operation is concerned, experience with evaporators seems to have been satisfactory. The cleaning of the standard types is a simple process and the expense of removing scale and dirt is of no consequence compared with that of removing the same amount from boilers and economizers where it might collect, if it had not been trapped by the evaporator.

As part of the water evaporates, that remaining becomes saturated with impurities so it is necessary to blow down the evaporator, either continuously or intermittently, in order to maintain efficient evaporation. In the case of fresh water, the blow down amounts to 4 or 5 per cent of the amount evaporated.

Removal of scale from the tubes in evaporators is effected either by cracking or by scraping. With the former method, the scale is cracked off by the expansion and contraction of the tubes when the temperature is suddenly changed. With certain types of evaporators, satisfactory scaling conditions may be had at one temperature condition but not at others. Some evaporators on the market have comparatively straight tubes, sometimes bent slightly to take care of the expansion due to changes in temperature, but in which the flexure is not counted upon to scale

the tubes. This type of evaporator depends upon the use of a tube cleaner to remove the scale.

Deaeration and Deactivation

Having solved the problem of preventing scale formation in the boiler, either by the use of chemical treatment or by distillation, it would seem that boiler troubles due to the condition of the feed water would be at an end but

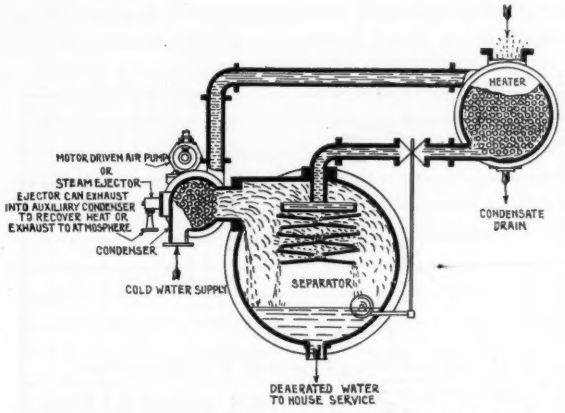

HEATER
MOTOR DRIVEN AIR PUMP OR STEAM EJECTOR
EJECTOR CAN EXHAUST INTO AUXILIARY CONDENSER TO RECOVER HEAT OR EXHAUST TO ATMOSPHERE
CONDENSATE DRAIN
CONDENSER
COLD WATER SUPPLY
SEPARATOR
DEAERATED WATER TO HOUSE SERVICE

FIG. 4. SECTION THROUGH A TYPICAL DEAERATOR

such is not the case. In fact, the production of absolutely pure water by distillation has only brought the problems of the corrosive action of gases and leakage of condensing water into the condensate more forcibly to our attention.

The theory that corrosion and pitting of steel piping, boilers, economizers and heaters is due to dissolved gases, especially oxygen, in the feed water, has resulted in the development of two types of deoxygenating apparatus, the deaerator and the deactivator.

The deactivator, used for small installations where the total demand for water does not exceed 1000 gal. per hr., produces water with no gas content, by permitting the dissolved gases to be expended on material that is cheap and readily replaced. The deaerator actually takes the oxygen and other dissolved gases out of the water by boiling it violently under reduced pressure.

Briefly, the deactivator is a large tank filled with special deactivating steel lath or other finely divided steel, through which the water is circulated. The water is allowed to corrode the inexpensive steel lath which is so arranged that when it becomes completely corroded, a new supply can be inserted. Since the activity of the dissolved gases varies with the temperature, the water in the deactivator is usually heated so as to accelerate the process. Heating is accomplished by steam coils within the tank.

Deactivators are available in sizes up to about 1000 gal, an hour capacity. Experience has shown that at a temperature of 160 deg. F., the water must circulate through the tank for about 1 hr. before sufficient oxygen is removed to make the water inert. The storage tank should, therefore, have a capacity to hold at least one hour's supply.

In large plants, where the demand for water is considerably in excess of 1000 gal. per hr., oxygen removal is more satisfactorily effected by the deaerator. The deaerator works on an entirely different principle from that employed in the deactivator. The arrangement is shown in Fig. 4. Water from the heater flows to the separator where a vacuum is maintained and the temperature of the water immediately drops to that corresponding with the vacuum carried. This results in explosive boiling. A portion of the water flashes into steam and all dissolved gases are thrown out. The steam and gases released by the explosive boiling are carried to the condenser where the vapor is condensed and returned to the separator, and the gases removed by the air pump or ejector.

Recirculation of Boiler Water

A recent development in the purification of boiler feed water is the recirculation process, in which a small quantity of water, say 25 per cent of the amount fed to the boiler, is continuously withdrawn from the boiler, filtered to remove suspended solids and returned to the boiler through the mud drum. The equipment consists esentially of a filter, a small centrifugal pump, built integral with the filter, together with suitable piping connections for effecting the removal and return of water to the boiler.

For its effectiveness of operation, this system depends largely upon maintaining proper relations between various scale-forming impurities in the feed water so as to bring about their precipitation. This maintaining of correct relationship between these impurities is accomplished by the introduction of chemicals into the water before delivery to the boiler.

Methods of Heating the Feed Water

Heating with Live Steam, Stage Heating by Bleeding. Use of New Venturi Heater

METHODS OF HEATING feed water have undergone considerable development in recent years, particularly in the central station field where there has been an increasing tendency toward the use of electrically-driven auxiliaries. In the days before heat balance was a familiar term, exhaust steam was plentiful around the power plant and the most economical method of heating the feed water to use this exhaust steam. In industrial power plants, of course, this is still the logical method and one that is extremely economical.

Stage Bleeding Is Now Commonly Used

As central stations became larger and the prime movers more efficient, it was obvious that the steam generated in the boilers would be most economically used, if sent into the prime mover; as a consequence, use of the electric motor for driving auxiliaries became more prevalent. This, however, curtailed greatly the available amount of exhaust steam for feed-heating purposes. So the idea of stage or bleeder heating was developed and today the designer is confronted by elaborate systems of this type, all of which extract a portion of the steam passing through the main unit at various points during its expansion and apply it towards heating the feed water. Heat for feed heating is also abstracted from flue gas and turbine glands.

Considering the industrial power plant, the simplest and most effective method of bringing the feed water to

a temperature close to that of the water in the boiler is to heat by exhaust steam in an open heater. The open heater, furthermore, as already explained, acts to some extent as a purifier. In most commercial types of open heaters, the feed water enters at the top and is distributed over a series of trays, so arranged that the water is forced to fall in a finely divided stream before reaching the reservoir at the bottom. The exhaust steam, coming in contact

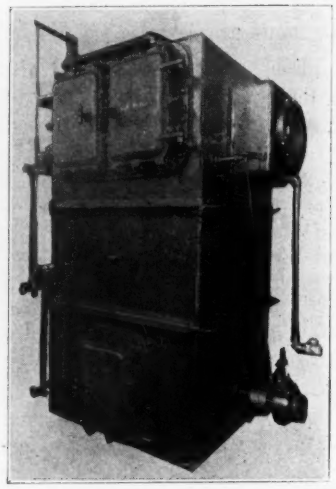


FIG. 1. A TYPICAL OPEN FEED WATER HEATER SHOWING METHOD OF CONTROLLING WATER SUPPLY BY FLOAT-OPERATED MECHANISM

with the water particles, gives up its latent heat and condenses. Float arrangements are usually provided, which regulate the water supply to the heater and provision is also made for the removal of solid impurities.

Closed Heaters

Closed heaters resemble condensers insofar as their principles of construction are concerned. They usually

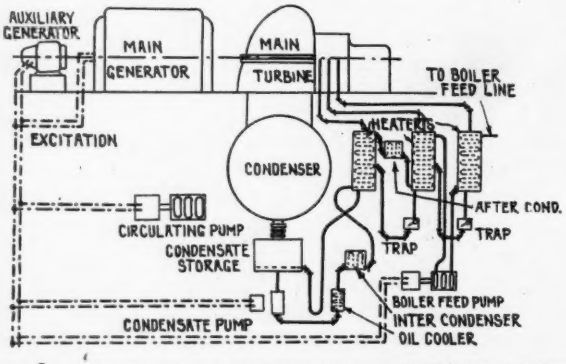


FIG. 2. ARRANGEMENT FOR HEATING FEED WATER, USING SHAFT-DRIVEN AUXILIARY GENERATOR FOR OPERATING AUXILIARIES

consist of a chamber filled with banks of brass or alloy tubes, through which the water to be heated is passed. Exhaust steam entering the chamber gives up its heat to the water in the tubes and is condensed in the same manner as in an ordinary surface condenser.

Up to a temperature of about 180 deg. F., the laws governing heat transmission in the closed heater are practically the same as those governing heat transmission in surface condensers. An increase in velocity of the water through the tubes increases the rate of heat transmission, thus rendering the heating surface more effective. In order, therefore, to secure reasonably high velocities and at the same time allow sufficient time in which to raise the temperature to the required value, the path of travel of the water through the tubes is made as long as possible, and the tubes are made of small cross-sectional area. Things being equal, a closed heater with a large number of tubes

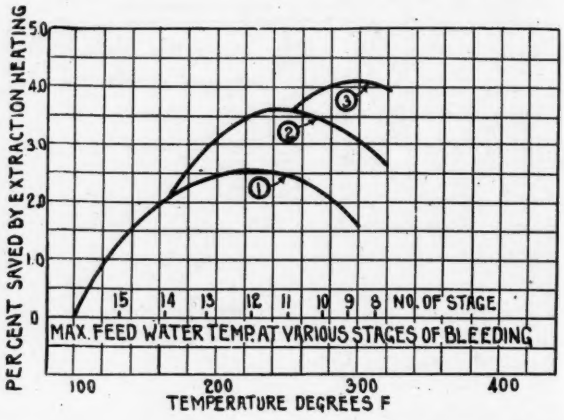


FIG. 3. GAIN IN USING MULTI-STAGE HEATING IN PLANT WITH LOW BOILER AND ECONOMIZER

of small cross-sectional area is more efficient than one having a small number of tubes of large area.

Heating with Live Steam

Feed water heating by the use of live steam is not considered economical and should be done only in emergency. Steam, whether live or exhaust, is valuable as a heating medium mainly by virtue of its latent heat. The total heat content of live steam is only slightly higher than that of exhaust steam, so it is obviously wasteful to use live steam, which has the capacity to do considerable mechanical work for purposes of heating when exhaust steam, which has almost the same heating power, is available. Of course, there are times when the required amount of exhaust steam for heating the feed water will not be available and, at such time, the only alternative is to use live steam.

Stage Heating by Bleeding

In large plants, the heating of feed water by means of steam bled from the main turbine is becoming common practice and is proving highly satisfactory. It is, in fact, accepted as the most efficient method for large central stations. The main steam turbines in such stations are the most efficient users of live steam; that is, more of the potential mechanical energy in the steam can be realized by passing it through the prime mover than any other machine in the plant. It is desirable, therefore, to send practically the entire steam output into the turbine and to operate the auxiliaries by electricity derived from the main units. This, however, leaves us with no exhaust steam with which to heat the feed water. In order, therefore, to secure low-pressure steam for this purpose, the idea was conceived to extract steam from the main unit at various intermediate stages. This method resulted in

a number of distinct advantages. First, an ample amount of low pressure steam was made easily available in quantities just sufficient to satisfy the varying demands; second, it permitted the use of large, efficient steam turbines, and relieved the low-pressure ends of handling some of the steam sent into the high-pressure end. This is an obvious advantage.

In some cases, a separate generator is provided for supplying current to the auxiliaries, but this generator is

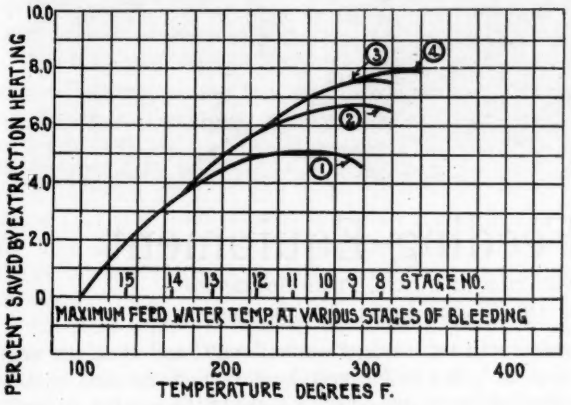


FIG. 4. GAIN IN USING MULTI-STAGE HEATING IN PLANT WITH HIGH BOILER ONLY

driven by the main turbine and is attached to the end of the main generator shaft. The method of extracting steam for feed heating is the same as if the current for the auxiliaries were secured direct from the main unit. Such an arrangement is shown in Fig. 2. The condensate, it will be noted, is heated gradually by means of steam bled from three stages on the main turbine. The condensate from each of the three closed heaters, as shown, is trapped and is delivered into the condensate storage tank.

Relative Effect of Stages in Heating

In any case, the major gain with bleeder heating is made in the first level extraction and the gain for each additional level at which the main unit is bled in about one-half the gain resulting from the preceding extraction. In the Prime Movers Report of the N. E. L. A. on heat balance for 1924, an analysis of conditions with a General Electric turbine was made This machine operated under a maximum load of 28,000 kw. with an assumed vacuum of 29 in. The condensate is heated to approximately 100 deg. either by gland steam or by a combination of the generator air and oil coolers. Two studies are shown in Figs. 3 and 4. Figure 3 shows the gain when using a low boiler and an economizer. It indicates that the net gain for single level bleeding is 2.6 per cent; that increasing to two levels adds an additional 1.0 per cent gain, and then increasing to three levels adds another 0.5 per cent gain.

Figure 4 shows the results of a similar study for a high boiler without an economizer. This indicates that single-level bleeding gives a net gain of 5.2 per cent; that the second level bleeding gives a gain of 1.5 per cent; and that the third level bleeding gives an additional gain of approximately 0.9 per cent.

There has been some uncertainty as to the effect of superheated steam on the transfer of heat from gaseous to liquid bodies in extraction heaters, the general impression being that it is much lower from superheated steam to water than it is from saturated steam. To avoid an error due to this fact, in determining the heating surface required in bleeder heaters, experience seems to indicate that in figuring the size of heating surface required, the bled steam should be considered as saturated steam at a temperature corresponding to the pressure of the superheated steam. If this is done the error will be small.

The closed type of heater used as bleeder heaters, are usually vented either to a lower level of heating or to a lower stage of the turbine, either of which apparently gives good results. The deaerator type heater, frequently used as a plant heater, has to be vented and in this case the heat in the escaping vapor is condensed by the incoming cold water, irrespective of whether it is below atmospheric pressure and a steam ejector has to be used, or whether it is above atmospheric pressure and no ejector is needed.

Venturi Feed-Water Heaters

An entirely new development in feed water heaters for stage reheating systems is the multi-stage-venturi heater. The action of this heater is based on the simple law of hydraulics that the sum of the static head, pressure head and velocity head at any point in a pipe are equal to the sum at any other point, disregarding losses. Since these heaters, as shown in Fig. 5, use the principle of the Venturi tube for their proper functioning, the inlet pressure of the water to the heater can be raised sufficiently higher than the discharge pressure to compensate for friction losses; then the stream of water is reduced sufficiently in area at the beginning of the first stage so that the pressure is less than the steam pressure of the lowest stage of the turbine to be bled. The temperature of the water at

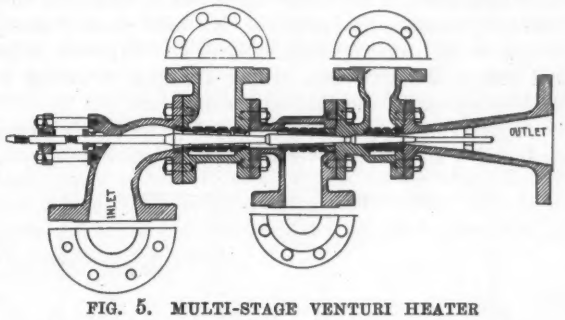
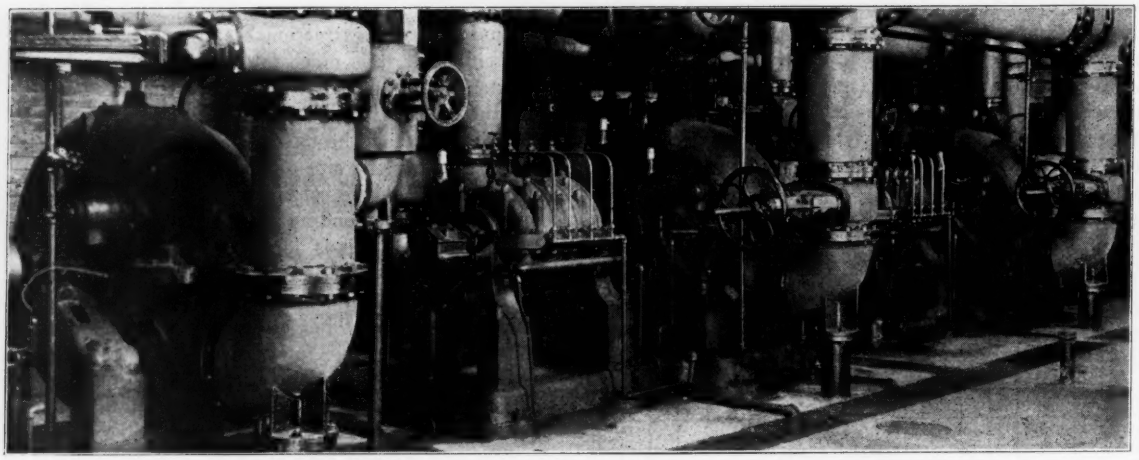


FIG. 5. MULTI-STAGE VENTURI HEATER

this stage is increased, by introducing the proper amount of steam, to within a few degrees of the temperature corresponding to the pressure of the steam used.

At the second stage, the pressure of the gradually increasing cross section of water, although higher than at the first stage, is lower than the steam pressures of the next higher stage of the turbine, from which the steam is bled. By introducing the proper amount of steam, the temperature of the water in the second stage is raised to within a few degrees of the temperature corresponding to the steam pressure. The next or succeeding stages use the above principle. At the end of the last stage, the area of water is further increased by means of a proper delivery nozzle. This nozzle changes the velocity head back to a sufficient pressure head to allow the water to enter the boiler.



Operation of Boiler Feeding Equipment

ARRANGEMENT OF PIPING AND VALVES, OPERATION OF PUMPS, PUMP GOVERNORS AND FEED WATER REGULATORS, PRIMING AND WATER LEVEL ARE DISCUSSED

IN THE operation of putting feed water into a steam boiler after having given it such feed water treatment as may be necessary, in accordance with the foregoing discussion, one of the important considerations is that of the arrangement of the boiler feed piping and valves. The system must be capable of supplying feed water to any one of the boilers, at the will of the attendants, in case other boilers in the battery are shut down.

It is common practice to provide two methods by which water may be fed to boilers, depending somewhat upon local conditions and the availability of feed water. Sometimes, in addition to the regular feed water lines from the boiler feed pump, a city water connection is made, but only if boiler pressure is low, since the city main pressure rarely exceeds 60 lb. In many other cases we find duplicate boiler feed pumps and the main piping arranged according to the loop system or the parallel main system.

Figure 1 illustrates the loop system with a main shown at A and a single crossover at B, each boiler being provided with two distinct connections C and D to the main loop A. Any boiler may be taken off the line without affecting the others. Figure 2 shows the parallel or double system of piping for the feed water system. In general, main A is used for regular operation and main B as the auxiliary shutoff by the valve C until it is required. Each boiler in this case is also provided with two distinct connections—one to each main, as shown at D and E. Main A may be constructed in a loop, in which case the main B forms a crossover for each boiler. With proper layout and arrangement of valves, the same feed water regulator check valves and controls may be used with either the regular or auxiliary main.

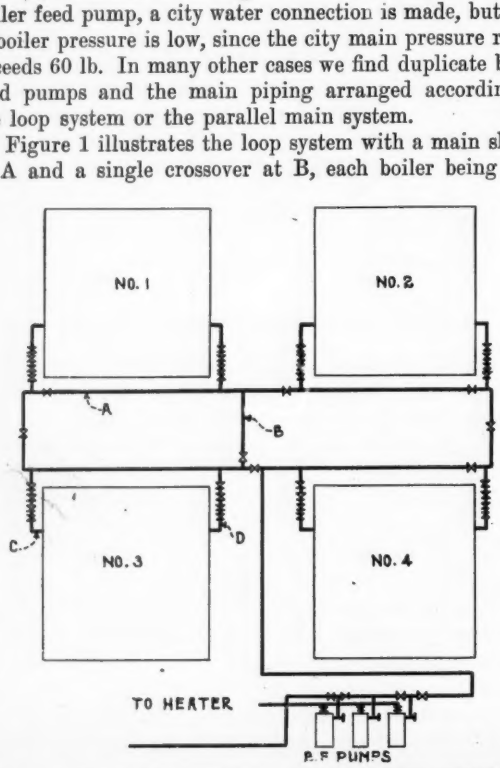


FIG. 1. SIMPLE LOOP SYSTEM OF BOILER FEED PIPING

Figure 3 shows a typical feed water piping arrangement for a condensing plant. In this arrangement cold water and condensate from the discharge pumps go to a hot well, from which the feed pumps take their supply. Pumps are in duplicate and all equipment is by-passed as indicated.

Extra heavy material should ordinarily be employed for boiler feed pipes, the size being chosen in most cases to limit the velocity to 300 or 400 ft. a min. Various methods are used to connect boilers to the feed water lines. It is good practice to have sufficient valves in the main pipes to enable any one of the boilers to be removed from the line by the use of gate valves, since these are either kept wide open or closed tightly. The number of these gate valves, however, should be reduced to the absolute minimum, since they require attention to keep them free of sediment.

In the boiler connection there should be a gate valve, a globe type regulating valve, if the boiler is hand regulated, a check valve and, preferably, a second gate valve, so that the regulating valve can be closed off when necessary to remove it for repairs. In case automatic regulation is provided, the regulator should, of course, be provided with a by-pass and a hand regulating valve, in order to insure continuous operation if the regulator has to be taken out of service.

Each branch from a boiler feed pump should be provided with a stop valve of the gate type, so that the pump may be disconnected from the main. A check valve and a pressure relief valve are usually placed between this stop

valve and the pump. The relief valve is used with the idea of protecting the pump, rather than the main, since pumps have many times been started with the discharge valve closed.

Feed water should be introduced at the bottom of the economizer and discharged from the top with the flow of water in a direction opposite to that of the gas. Sometimes, however, the installation is of such a nature that water is both received and discharged at the top of the economizer. In this case the upper manifold should be blanked so that water will not take a direct path from inlet to outlet.

When a feed water heater of the steam tube type is employed, water should be introduced into the heater at a low point and discharged at a high point with a blowoff at the extreme top of the heater to remove impurities. The heater should be by-passed and a relief valve should be placed between the inlet and outlet water valves on both closed heaters and economizers to protect the apparatus if the heat should be turned on when the valves are closed. Relief valves used for this purpose need not be over ¾ in. in size.

Injectors afford a method for feeding warm water when the heater may be out of service, since feeding boilers with cold water might cause damage in excess of the cost of an injector. It is usually connected with the same suction discharge and steam lines as a pump, using a stop valve for each of the three branches.

Methods for discharge of the feed water into the boiler are well taken care of by the provisions of the A.S.M.E. Boiler Code and the boiler codes of various states. In general, the discharge into the boiler should be in that portion where boiling is least violent and the water should not discharge near a riveted joint or furnace sheet.

One other point to bear in mind is that every fitting used in boiler feed lines adds materially to the friction head that must be overcome by the boiler feed pumps. For example, 200 g.p.m. through 4 elbows, 2 globe valves and 400 ft. of 4-in. pipe gives a total resistance head of 13.25 ft. of water or 5.75 lb. per sq. in. when discharging into an open tank. Tables of the friction loss through various pipe fittings can be obtained from the various manufacturers and will prove extremely useful in laying out boiler feed lines.

Proper operation of boiler feed pumps depends on two

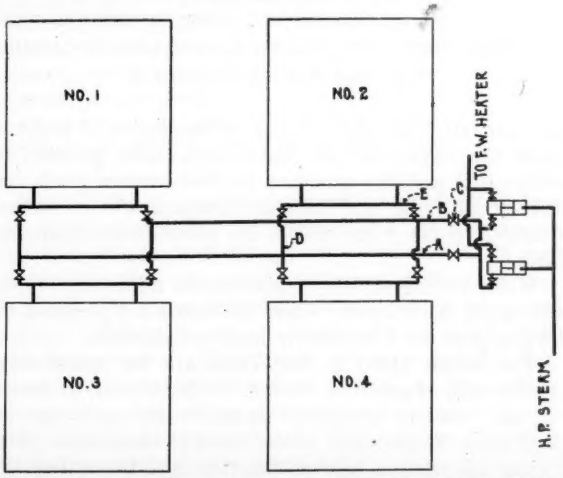


FIG. 2. DOUBLE MAIN OR PARALLEL SYSTEM OF FEED PIPING

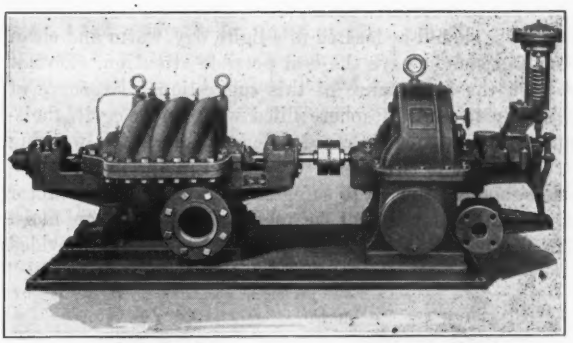


FIG. 4. MODERN TYPE OF TURBINE DRIVEN CENTRIFUGAL BOILER FEED PUMP

factors: proper installation and careful operation. Various types of pumps are used for boiler feeding and the following comments on the method of installing them will apply to almost all types. Centrifugal pumps may be direct driven by steam-turbine, electric motor or belt from an engine, line shaft or other source of power. Typical examples of these are shown in Figs. 4 and 5. Reciprocating pumps may be direct acting, either duplex or single. Triplex plunger pumps as in Fig. 6 have also been used for boiler feed pumps. These may be driven by various prime movers; they are often motor driven through spur gears or speed reducers.

Centrifugal pumps are used for boiler feeding in many cases, especially in the newer and larger plants. They lend themselves well to direct drive by motor or turbine.

In order to obtain the highest overall plant efficiency, many engineers favor motor driven auxiliaries in some cases, supplementing them with steam driven auxiliaries as a stand-by. When starting a centrifugal pump driven by electric motor, it is customary to keep the discharge valve closed until the motor is up to full speed. In case of d.c. motors, the bringing of the motor up to speed presents no special difficulties, the range of speed required for boiler feeders being easily attainable by a simple field control. It should be noted here that the full load and low load speeds of most motors vary by considerable amounts, and the correct speeds for these loads should be obtained from the motor builders so that they can be provided for in designing the pump.

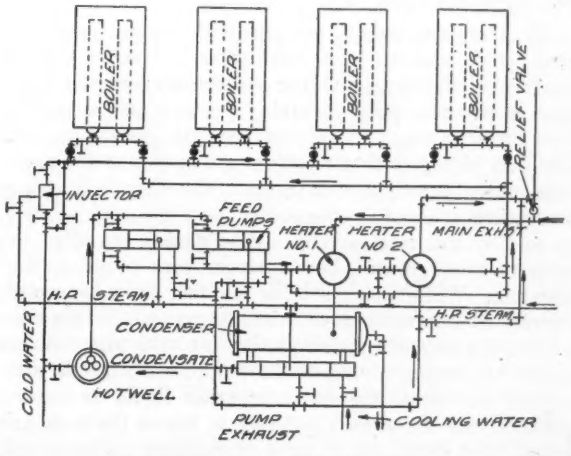


FIG. 3. ARRANGEMENT FOR TYPICAL CONDENSING PLANT

Pumps should be located in a light, dry, warm and clean room and should have the best possible attention. Do not overlook the importance of this suggestion. Exposure of the pump to an atmosphere filled with smoke, grit, moisture or dirt will cause rapid deterioration of the working parts. When it is necessary to locate pumps in pits, provision should be made to safeguard against floods. Motor driven units should not be operated in damp or moist places, unless this condition has been especially provided

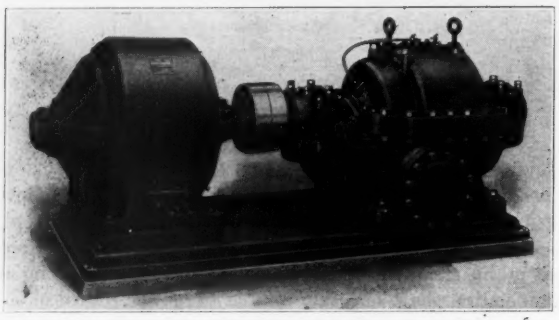


FIG. 5. DIRECT-CONNECTED MOTOR-DRIVEN CENTRIFUGAL PUMP FOR BOILER FEED SERVICE

for and the proper motor purchased. The pump should be located so as to be accessible for inspection during operation and there should be ample head room to allow the use of an overhead crane, hoist or supporting structure of sufficient strength to lift the heaviest part of the unit. The pump should be located as close to the source of supply as possible. If it can be done, place the pump below the level of the liquid in the suction reservoir so that the liquid will flow into the pump by gravity when the suction valve is opened, and the pump thereby becomes self priming.

A substantial foundation is absolutely necessary. It may be of any suitable material that is sufficiently rigid to permanently support the pump at all points, and to absorb any normal amount of vibration that may develop from any cause. When a pumping unit is mounted on steel work or other structure, it should set directly over or as near as possible to the supporting beams and walls. It must be supported in such a way that the base plate cannot be distorted and the alignment disturbed by any yielding or springing of the structure.

On large size pumps, use pipe with flanged joints and good grade gaskets. On small sizes the screw type of joint is satisfactory providing the threads are well made up. If possible, keep all piping exposed and accessible. Care must be taken to support properly the suction and discharge piping so that no strain can be put on the pump from either its weight or expansion; therefore, before final connections are made to the pump, the joints must be made up so they will meet exactly. Pipe strains are often the cause of misalignment, hot bearings, worn couplings and vibration. While piping is being laid and pump connected, extreme caution must be exercised to prevent foreign matter, sand, grit and rubbish getting into the pipe. Before finally connecting piping to the pump, wash it out thoroughly, and while the water or other liquid is passing through, rap the pipes vigorously to loosen the scale and oxide.

The suction piping should be as direct and short as possible. It should be the full size of connection, as called for on pump, and not have any branches. If the suction line is long the size should be increased. Care must be taken to guard against air pockets and not to install piping so it moves up and down, thereby permitting a possibility of air entrapping in line. The suction pipe should be blanked off and a water test put on for air leaks before starting up.

A boiler feed pump taking its water from an open feedwater heater should be installed so that the head on the suction is never less than the minimum given in Table I.

Manufacturers of pumping machinery always specify the size suction pipe to be used with each size pump for the best results. For long suction pipes or high suction lifts, a vacuum chamber and a foot valve should be used. The diameter of the suction pipe should be such that the velocity of the water does not exceed 240 ft. per minute.

For long or high suctions a vacuum chamber on the suction side of the pump is an advantage and is particularly recommended for simplex pumps, all fire pumps, and any pumps which are operated at high speed, especially for pumps of short stroke. For ordinary conditions centrifugal pumps do not require suction air chambers, but when the water contains a large percentage of air, a vacuum chamber, to which is connected a vacuum pump or air ejector for removing the excess air, is sometimes used.

Too much attention cannot be given to the suction conditions of any pumping installation. Failure to ob-

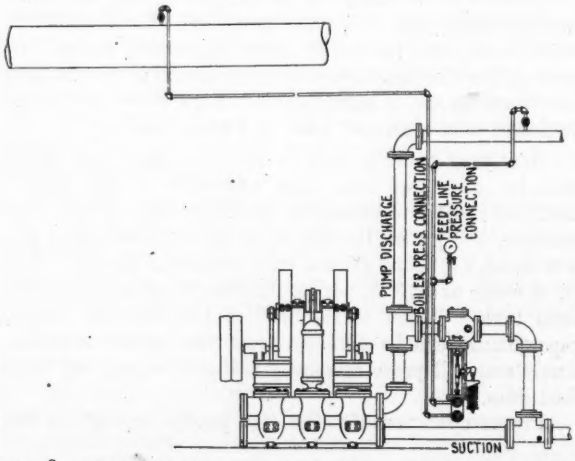


FIG. 6. POWER DRIVEN TRIPLEX PUMP, SOMETIMES USED FOR BOILER FEED WORK, SHOWING REGULATOR BY-PASSING DISCHARGE AND SUCTION LINES

serve fundamental rules relating to the suction of a pump means the failure of the installation. The permissible suction lifts and the necessary positive suction heads for different altitudes and different temperatures of water, computed by one pump maker, are given in accompanying Table.

Where the values are preceded by the minus sign (—), suction lift is indicated; where the values are preceded by the plus sign (+), a positive head is indicated.

The values given in the Table are for water only. Liquids such as gasoline, alcohol, crude oils, tar, molasses, etc., etc., must be considered separately and each case decided upon the character of the liquid to be pumped. Fig. 7 gives the relation between practical and theoretical lift at sea level for various temperatures, as allowed by a sec-

ond manufacturer. A slight variation will be noted here from the values noted in the table.

Whenever a pump located below the source of supply or when it takes liquids from a system of piping under pressures, it is necessary to place a gate valve in the suction line close to the pump. It is then possible to open the pump for inspection, cleaning or repairs without first draining the pressure suction system, and also to control

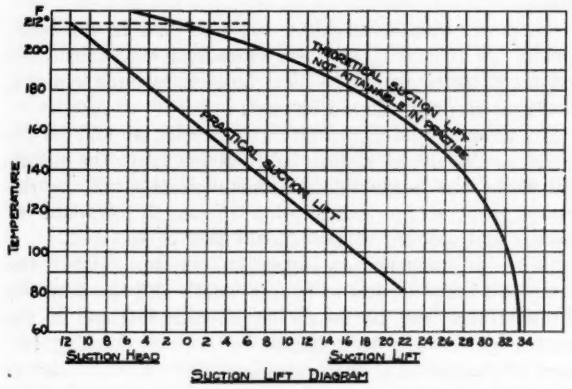


FIG. 7. PRACTICAL AND THEORETICAL SUCTION LIFTS UNDER BEST CONDITIONS AT SEA LEVEL

the capacity to a certain extent on the suction side of the pump.

Vaporization Must Be Prevented

In the preceding paragraphs the bad effects of operating a centrifugal pump at the critical capacity point were brought out. We find this same critical condition applies to boiler feed pumps handling hot water as the water temperature is at or near the boiling point at atmospheric pressure. Under these conditions it is necessary to arrange the pump with a positive head on the suction so that the absolute pressure existing at the pick-up part of the vane entrance is a few feet greater than that due to the temperature of the water.

TABLE. RELATION BETWEEN TEMPERATURE, ALTITUDE AND ALLOWABLE PRACTICAL SUCTION LIFTS OF PUMPS

Minimum Allowable Head in Ft. on Suction	Temperature of Water in Deg. F.															
	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210
At sea level	-22	-20	-17	-13	-13	-11	-8	-6	-4	-2	0	+3	+5	+7	+10	+12
At 2000 alt.	-19	-17	-15	-13	-11	-8	-6	-4	-2	+1	+3	+5	+7	+10	+12	+15
At 4000 alt.	-17	-15	-13	-10	-8	-6	-4	-1	+1	+3	+5	+7	+10	+12	+14	-
At 6000 alt.	-15	-13	-11	-8	-6	-4	-2	+1	+3	+5	+7	+10	+12	+14	+16	-
At 8000 alt.	-13	-11	-9	-6	-4	-2	0	+3	+5	+7	+9	+12	+14	+16	-	-
At 10000 alt.	-11	-9	-7	-4	-2	-0	+2	+4	+7	+9	+11	+14	+16	+18	-	-

Here, again, stage pressure as well as speed determines the amount of suction head required at a given temperature. This also leads to the adaptation of the double suction impeller type of pump as allowing of the least suction head for given temperatures and stage pressures. Roughly speaking, a steam turbine-driven multi-stage boiler feed pump of 160 to 180 ft. per stage and 212 deg. F. water requires a positive head of 8 ft. on the suction for normal capacity. If an over size, or lower speed pump is used, this head can be reduced. With very small pumps the conditions are not so accentuated.

If vaporization is allowed to occur, a solid body of water is not available for the first stage impeller and the pump quickly becomes vapor bound, and is thrown out of hydraulic balance. The unbalanced pressures result in burned out thrust bearings or thrust discs as the case may be and the unit is entirely out of commission.

Another cause leading to vaporization while not due to suction conditions can be considered at this time, and that is the closing of all the check or stop valves in the discharge line. During this period the pump is simply churning the water, which raises the temperature so that a vaporization condition soon exists.

The foregoing analysis emphasizes the necessity of using the greatest care when installing the suction piping for a pump for boiler feed service. The utmost care may be used in selecting and building a pump, but unless equal care is used when installing, it will prove a failure in operation.

A strainer with a net area of three to four times the area of the suction pipe should be installed on the suction pipe to protect the pump from getting any foreign material into the impeller or valves. For large pumps re-

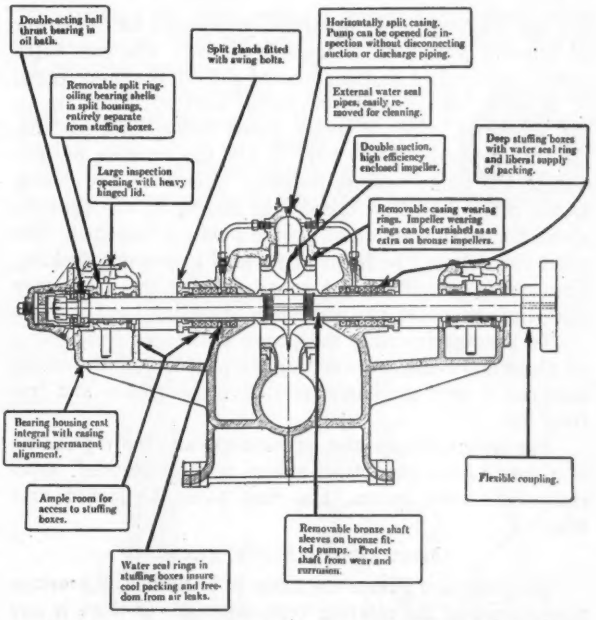

Double-acting ball thrust bearing in oil bath.
Split glands fitted with swing bolts.
Horizontally split casing. Pump can be opened for inspection without disconnecting suction or discharge piping.
Removable split ring-oiling bearing shells in split housings, entirely separate from stuffing boxes.
External water seal pipes, easily removed for cleaning.
Deep stuffing boxes with water seal ring and liberal supply of packing.
Double suction, high efficiency enclosed impeller.
Large inspection opening with heavy hinged lid.
Removable casing wearing rings. Impeller wearing rings can be furnished as an extra on bronze impellers.
Bearing housing cast integral with casing insuring permanent alignment.
Flexible coupling.
Ample room for access to stuffing boxes.
Removable bronze shaft sleeves on bronze fitted pumps. Protect shaft from wear and corrosion.
Water seal rings in stuffing boxes insure cool packing and freedom from air leaks.

FIG. 8. SECTION OF A TYPICAL CENTRIFUGAL PUMP

movable screens should be placed at the entrance to the suction well.

When the liquid flows to the pump under a head, a gate valve should be placed in the suction line for use when occasion requires.

When a stop valve is located in the suction line, a small spring relief valve should be installed between the pump and the stop valve to prevent pressure building up on the suction system by any contingency.

Connection of Pump Discharge

Standard practice among pump manufacturers is to furnish their pumps with all discharge passages connected to one common opening to which the purchaser connects the discharge pipe. The discharge line should be of ample size and with as few bends and fittings as possible in order to reduce the friction head to the lowest consistent point since excessive friction head is merely wasted energy.

The velocity in the discharge pipe should not exceed 300 ft. per min. for the best results.

The discharge pipe should be installed with a check valve and a gate valve near the pump outlet. The check valve protects the pump from excessive pressure and prevents a centrifugal pump from running backward as a water wheel in case the prime mover trips out and stops without the operator's knowledge. A gate valve is necessary for starting up a centrifugal pump and for repairing all types of pumps, or during idle periods. The gate valve should be installed on the outboard side of the check valve.

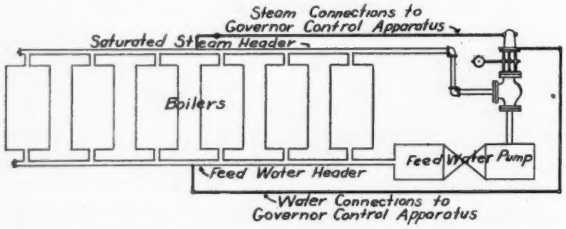


FIG. 9. WATER AND STEAM CONNECTIONS TO PUMP GOVERNORS ARE MADE IF POSSIBLE AT MID-POINTS OF HEADERS, TO MINIMIZE FRICTION LOSS

A relief valve should be placed next to the pump in the discharge pipe of every power-driven positive displacement pump. This valve is for the purpose of protecting the pump against breakage caused by the closing of the main discharge valve, thus increasing the pressure above the maximum for which the pump is designed. The relief valve should be frequently tested to prevent sticking. The spring should be set so as to open at a pressure slightly in excess of the maximum operating head.

To prevent freezing, the pump is drained by opening all plugs and cocks provided for the purpose. Non-freezing mixtures if used must be absolutely non-corrosive and free from grit.

The frequent inspection of packings and the regrinding of pump valves and other valves is recommended, especially on a new system, also that pump be looked over weekly.

Mechanical Adjustments

Reciprocating pumps are likely to be harder on bearings than pumps of the rotating type, especially if there is any pounding. For that reason it may be advisable to plan the inspection schedule to cover pumps of this type more frequently than is necessary in covering centrifugal pumps.

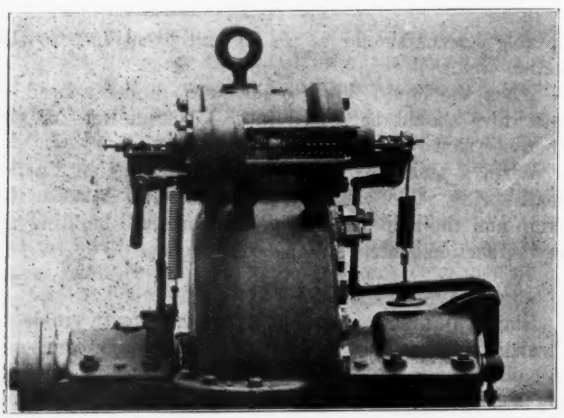


FIG. 10. EXCESS PRESSURE GOVERNOR CONTROLS STEAM SUPPLY TO TURBINE DRIVING THE PUMP, IN CONJUNCTION WITH THE TURBINE'S OWN GOVERNOR

A hard metallic knock just before the end of the stroke is usually due to water hammer in the steam end and can be remedied by opening the drip in the steam cylinder. If it continues, the steam chest should be drained by a drip pipe to carry away the water before it enters the steam cylinder.

In power pumps, attention must be paid to the bearings to see that they are kept clean and well lubricated and metal gears should be oiled but, on rawhide pinions, good graphite only should be used.

In plunger pumps, particular attention should be directed to the stroke action. If it is too long, the piston will strike the heads; if too short, capacity will be decreased, and steam consumption increased. Amount of leakage and amount of slip should also be watched.

When adjustments are correct and suction is tight, the pump will make strokes of proper length and the duration of all strokes will be nearly equal. Air leakage in the suction will usually be indicated by a quick shooting forward of the piston at the beginning of the stroke followed by a fairly steady pull to the end. Striking of heads may be due to clogging up of the cushioning ports or to improper setting of the valve stops, which latter may also cause short stroking.

Steam valves of simplex pumps are usually steam actuated. In some cases, an auxiliary valve operated from the piston is employed. For this latter case and for duplex pumps, the following rule for setting the valves will ordinarily apply.

Place the pistons in the center position as follows: With piston in striking position at each end, make marks on the rod against a gland; then mark the rod halfway between. When this mark is against the gland, the piston is in the center of its stroke.

When pistons have been placed in mid-stroke, the valve motion arms should be perpendicular; if not, adjust the crosshead to give this condition. Then remove the steam chest covers and place the valves in mid-position. As there is no lap, the outer edges of the valve will be in line with the outer edges of the steam ports. In this position, the tappets on the valve stem must be equidistant from their respective striking surfaces on the valve motion.

Valves need as much attention in the matter of leakage as most steam using apparatus. In pumps which exhaust into the feed-water system, leakage does not mean so direct a loss. Owing to their position in the steam line, the steam is usually quite wet at the pump with resulting wear of the valve surfaces. Refacing or renewal of bushings or rings must occasionally be done.

Priming and Starting Centrifugal Pumps

Centrifugal pumps must always be primed before starting; otherwise the interior parts, which depend upon the water for lubrication, will be injured. While priming, the pump must remain stationary and should never, under any condition, be operated without water. In other words, it should never be allowed to run dry or empty. As soon as the pump is primed; that is, completely filled with water, it is ready to start. It should now be started with the discharge valve closed. The pump will attain its normal speed in about 20 sec., after which the gate valve on the discharge may be opened.

If, after starting a centrifugal pump, it throws a little water at the first few revolutions and then churns and fails to discharge more, it is evidence that all of the air was not expelled from the pump and piping, or the suction lift is too great, or there is a leak in the suction piping, or an insufficient discharge head. Pumps with short, horizontal discharge pipes are sometimes difficult to start owing to the fact that the water is thrown out of the pump before the water in the suction pipe is fairly started. The remedy for this is to add a length of discharge pipe.

If, when first started, the pump throws a full stream for a few minutes and then fails, it is caused by failure of supply, or water in the well or pit receding below the suction limit, which in a well is best determined by a vacuum gage placed on the suction elbow of the pump. The remedy for this is to lower the pump, thus reducing the suction lift.

If the pump delivers a full stream of water at the surface, or level of the pump, but fails to pump at a higher discharge point, the speed of the pump is too low.

If the pump starts a full stream and then the discharge decreases slowly until the pump fails to deliver any water, it is caused by a leak in the packing gland. If, when the pump is started, it delivers and continues to deliver only a small stream of water, there are probably one or more air pockets wherein air has collected in such quantity as to decrease the effective area of the line. The pump may deliver a full quantity for a few hours and then fail, the speed and water supply being unchanged; in this case the suction pipe or impeller is probably obstructed. If there is a heavy vibration when running, the shaft has probably been sprung, the pump is out of alinement, or an obstruction has lodged in one side of the impeller. If the bearings heat unduly, the belt is unnecessarily tight, the bearings lack oil, or there is an end thrust.

In cases where it is necessary to operate the pump at a lower head than that for which it was designed or speeded, the gate valves on the discharge may be used to throttle the delivery and prevent pumping an excessive amount of water, which would generally mean an overload.

Boiler Feed Regulation

Continuous feed to a boiler as long as it is under load is a most desirable condition, as intermittent feeding causes variations in steam pressure and steam output. The supply of heat being more or less constant, any irregularity in feed uses more or less heat in bringing the water to the boiling point, while the latent heat required for a given load and pressure remains constant. The result is that either the load or the pressure must change.

When the boiler load changes, it is not possible to immediately adjust the heat supplied to the new load, so that it is desirable, in order to prevent changes in pressure, to change the feed water supply and thus absorb or supply the surplus heat.

Since an intermittent feed will cause the load to vary, it will be impossible to keep the same load on each of the boilers of a battery. Some will be underloaded and some overloaded.

It is common practice to raise the water level in a locomotive on down grade so that there will be a reserve capacity for use on an upgrade and less water is fed on the upgrade, lowering the water level. The same procedure is advisable in stationary practice.

Pump Governors Regulate Pump Discharge

Boiler feed pumps are often equipped with pump governors. These governors should be of the excess pressure type, as a constant difference in pressure across the control valves on each boiler greatly assists the ease in feed water regulation. The control connections to the pump governor should be arranged to give a constant ex-

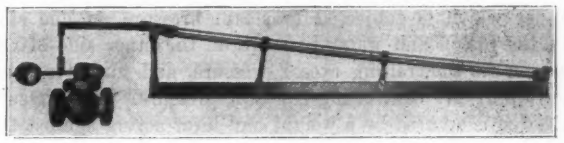


FIG. 11. EXPANSION AND CONTRACTION OF TUBE FILLED WITH STEAM AND WATER FROM BOILER ACTUATES BALANCED CONTROL VALVE

cess at the boiler feed control valves. This can be done by making the steam connection from the governor control apparatus to a saturated steam line near the boilers, or if this is not possible, to the main steam header near the boilers. In some cases, a one-inch saturated steam header is run from the boiler drums for the sole purpose of governor control.

The water connection from the governor control apparatus should be made to the main feed water header as near to the boilers as possible, preferably at some midpoint which would eliminate as much as possible the friction loss in the feed water lines, as shown in Figure 9.

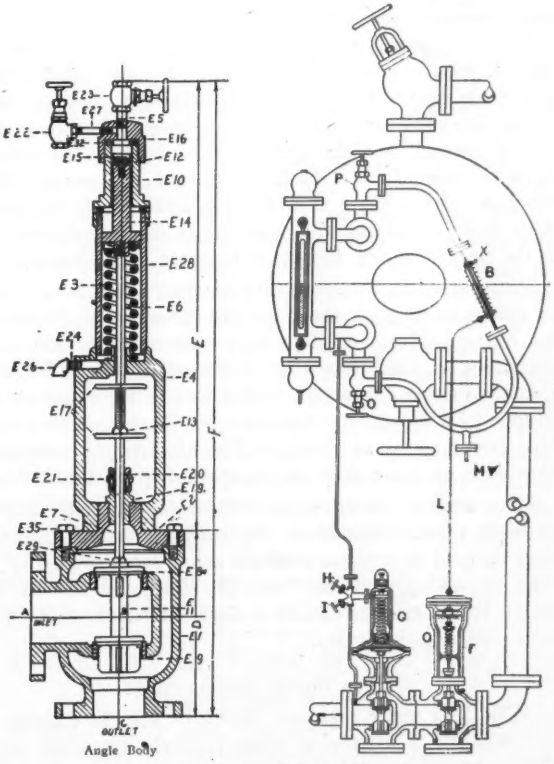


FIG. 12. ONE OF THE STANDARD TYPES OF PUMP GOVERNORS

FIG. 13. IN THIS FEED WATER REGULATOR, GENERATOR B PROVIDES VARYING PRESSURES TO ACTUATE VALVE. THE DIFFERENTIAL, EXCESS-PRESSURE VALVE G CAN BE PLACED ANYWHERE IN THE FEED LINE AHEAD OF THE REGULATOR

There are two general types of pump governors—constant pressure and excess pressure. Constant pressure governors are used for general pressure service where a constant pressure is required, such as house service, tank or accumulator.

Excess pressure governors are used extensively for boiler feed service. The governor shown in Fig. 9 consists of a balanced valve operated by a piston in a cylinder which is subjected to steam pressure on one side of the piston and water pressure on the other side of the piston for controlling excess pressure, and to water pressure only for controlling constant pressure. The pressure desired is secured by a weight and lever acting against the piston.

In the pump governor shown in Fig. 12, steam passes through the valve body directly into the steam chest of the pump. The spring inside the regulating cylinder holds the steam valves off their seats, allowing the pump to run until the discharge pressure reaches the point at which the governor is set. Discharge pressure is piped to the globe valve at the top of the regulating cylinder; this pressure acts against the spring and controls the movement of the steam valve. Adjustment on this governor is made by two wheels located just below the regulating cylinder in Fig. 12.

Another type of excess pressure governor utilizes the pressure on a diaphragm, the governor being placed in the pump discharge line and the valve being held open by steam pressure on top of the diaphragm. The valve can be so adjusted that the differential between water and steam pressures governs the area of the valve opening.

Use of governing equipment has now become general practice with engineers for regulating the discharge pressure from centrifugal pumps, regardless of whether the pumps are motor-driven or turbine-driven. In the event of the former, a differential water pressure regulating valve is placed in the discharge line of the pump. The function of the valve is that of a differential reducing valve and it maintains a constant excess water pressure in the feed lines over the steam pressure of the boilers.

When used in the steam line to a turbine-driven pump as shown in Fig. 4, the governor increases or decreases the amount of steam supplied to the turbine and thus maintains a fixed excess or differential, responding to changes in steam pressure and demands for water to be supplied by the pump. Sometimes it is applied to a turbine-driven pump as shown in Fig. 10, acting in conjunction with an emergency or overspeed trip on the turbine.

For triplex pumps, either belt-driven or motor-driven through direct connection, the excess pressure governor may be used as a water pressure relief valve as in Fig. 6. The by-passing of water from the discharge line of the pump to the suction insures a fixed discharge pressure of a predetermined amount.

Feed Water Regulation

The feed water regulator shown in Fig. 11 consists of a composition expansion tube properly mounted on a frame work connected to a lever to transmit the expansion of the tube and a balanced control valve.

The tube is mounted at the water level in the boiler and connected to the steam and water space of the boiler similar to a water column. The tube is sloped so that more or less of the tube is filled with water as the level in the boiler varies. The upper part of the tube being filled with steam, the expansion of the tube is determined by the relative quantities of steam and water. This expansion holds the control valve open the required amount to feed the boiler properly. The expansion tube acts as a manometer so that care must be taken in running the connections to the boiler that no traps or level spots are left in the steam line, or no globe valves are used, and if the steam line is over 12 ft. long, it should be covered with lagging. The water line should be dropped several inches from the boiler and run horizontal, thence up to the thermostat to prevent thermal circulation in this line.

Irrespective of how carefully the location of this regulator is made with respect to the water level in the column, the level should be checked by squirting water along the outside of the tube. This will show the level in the tube which should be near the center when normal level is carried in the glass. It is usually best to connect both steam and water lines to the same drum to which the column is connected. Steam connections are not made to steam lines used for other purposes, nor are water connections made to the bottom of the boiler or to the feed line.

Figure 13 shows another well-known type of feedwater regulator. In this device, a generator is used, this generator consisting of a tube surrounded by a radiator connecting by a pipe L with the diaphragm Q of the control valve on the feed line. With the water level as shown in Fig. 13, the steam above the water line in generator B adds heat to the water in the lower part of B, thus creating a slight additional pressure in this water column. This pressure is transmitted through L to the valve and tends to open it against the pressure of the spring. When the water level in the boiler is rising, the steam space in the generator B is becoming smaller, the pressure on the water due to heat added is less and the valve tends to close. In short, this regulator opens the boiler feed line valve when the water level in the boiler is going down and closes the valve when the boiler water level is going up.

Another type of feed water regulator uses a harp column of heavy copper tubes connected to steam and water spaces of the boiler. Expansion and contraction of the harp depends on the proportion of the pipes that are filled with steam and water and this expansion and contraction are transmitted to a thermal valve, which regulates steam pressure on top of the diaphragm of a regulating valve in the feed line, thus closing or opening it. The action is continuous and the feed valve is almost always open under normal operation, allowing a continuous, steady feed, with provision for gradually increasing this feed as boiler water level falls and gradually decreasing it when the level rises.

High boiler ratings, high furnace temperatures and comparatively small water storage space in modern boiler practice necessitate sensitive water level adjustments; every change in load should be met with a change in feed water input. A steady water level with variable loads is wrong and so is a variable level with a steady load. Water level in a boiler influences priming, degree of superheat, ability to operate at high ratings and, most important of all, safety.

If the boiler has such a small storage space that it would go dry if the feed were cut off for only a short time, then the slightest change in load would have to be accompanied by a change in flow of feed. But an actual boiler holds considerable water and it is not necessary to

change the supply of feed instantly. Instead, when a sudden load comes on, some of the water already in the boiler can be allowed to evaporate into steam, lowering the water level to its lowest permissible point. Conversely, when the steam demand drops off, the amount of water in the boiler can be increased and heat stored in it. In Fig. 14 is shown the way in which an automatic regulator will adjust the rate of feed to varying load conditions.

Causes of Priming

Priming may be caused by high water, forcing of the boiler, rapid change in load and, to some extent, by the type of boiler, but the principal cause of it is surface tension caused by sodium salts in solution, the sulphate being the worst form.

In simple terms, these salts form an armor over the surface, resisting the effort of the steam bubbles to break through, until the pressure beneath the surface is built up to the degree that a miniature explosion takes place, resulting in a rush of steam which carries up with it slugs of water. This condition can be easily observed in the laboratory by boiling rapidly water containing a large amount of soluble material. Evaporation will take place intermittently, in a bumping, noisy fashion, and at times so violently that the water will be partially expelled from the container, similar to the slugs that are common in priming boilers.

Aside from the danger to reciprocating units and turbines, priming is bad in increasing the friction in piping, due to the deposits left by the wet steam, coating and cutting of turbine blades, need for increased lubrication, and wasting heat because the water thrown

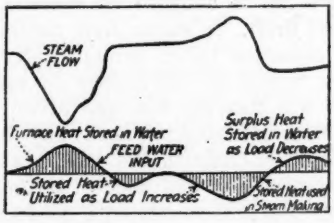

STEAM FLOW
Furnace Heat Stored in Water
FEED WATER INPUT
Surplus Heat Stored in Water as Load Decreases
Stored Heat Utilized as Load Increases
Stored Heat used in Steam Making

FIG. 14. RELATION BETWEEN STEAM OUTPUT AND WATER INPUT WHEN REGULATOR IS ADJUSTED TO STORE HEAT

out has taken fuel to heat it, but is of no use in furnishing power.

Nearly always, when priming occurs with low concentrations, the cause can be traced to oil contamination of the feed water. As little as 1 grain per gallon of oil may interfere seriously with the free generation of steam. Where caustic soda is contained in the boiler, compounded oils cause the greatest trouble, as they form soap and greatly aggravate conditions. It is best to change to a pure mineral oil, and take steps to eliminate it from the feed and condensate.

Separators within the steam drum are becoming more commonly used, but it should be remembered that they are not designed to prevent priming and foaming, but to correct some of the effects of those actions. In general, there are two classes, the baffle and centrifugal types.

Operation of a centrifugal type separator is plotted on Fig. 15. It will be noted, that as the rating increased, the moisture content decreased. This is to be expected, in that this type of separator depends upon velocity for its efficiency. The exact reverse is true of the baffle type, which depends upon low velocities of steam for best results.

Control of Concentration Prevents Priming

One of the important considerations in the prevention of priming, is a careful control of the boiler concentra-

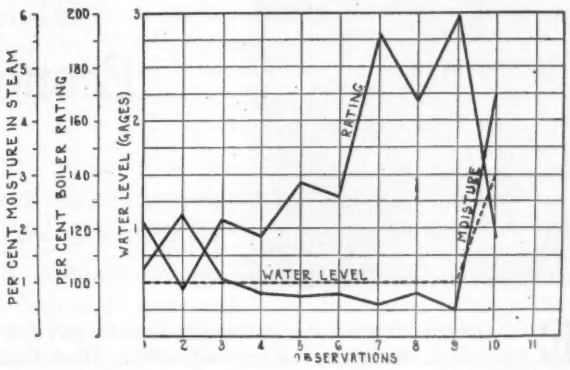


FIG. 15. CHARACTERISTICS OF A CENTRIFUGAL SEPARATOR INSTALLED IN A BOILER DRUM, AS SHOWN BY TEST

tions. It is interesting to note, however, that there is a different priming point for each rating. Thus, in the foregoing tests, it was pointed out that with concentrations of approximately 60 grains, a rating of over 200 per cent could be carried quite easily, while at 100 per cent rating, a concentration of total solids of over 280 grains could be carried without experiencing wet steam.

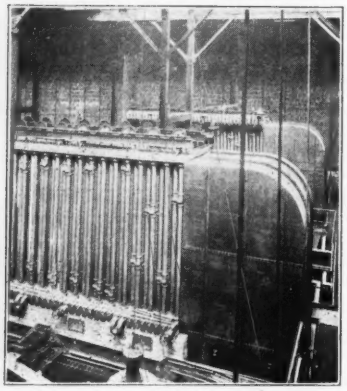
It has been pointed out that two methods can be employed to make control of concentrations effective; namely, that of blowing down and the use of barium salts—in this case, barium hydrate.

Of the two, blowing down is preferable, because of its much lower cost and ease of regulation. There is a well-established opinion among boiler plant operators, nevertheless erroneous, that blowing down a boiler beyond a fixed schedule is expensive, even under priming conditions. It must be remembered, however, that a priming boiler, in effect, is blowing down itself through the steam outlet. Considering the probable effect of neglect of blowdowns to reduce concentrations, in the way of certain types of expensive repairs and shutdowns, the fallacy of blowing down without knowledge of concentrations is apparent.

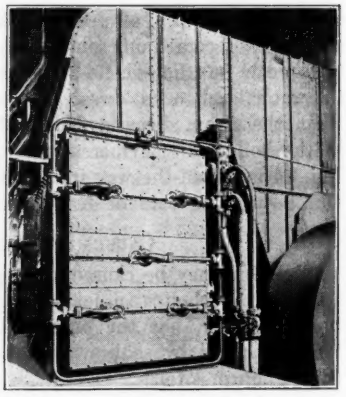
Chemical treatment with barium hydrate should be used with caution and is to be recommended only with waters high in sulphate content. In this connection, there is another point to be considered. Where the boiler water is alkaline the possibility of caustic embrittlement must be considered. It has been emphasized by authorities on this subject, that no case of caustic embrittlement has ever been cited where the relation of sulphates to alkaline sodas is one to one. In all known cases of caustic embrittlement, the boiler waters were always low in sulphates and chlorides.

Iron Mountain Plant Makes Power from Wood Waste

In the article under the above title which appeared in the December 1, 1925, issue, we unintentionally omitted the statement that Lopulco pulverized fuel feeders and burners were installed on all boilers at the Iron Mt. Plant by Combustion Engineering Corp. At the time the article was prepared, only two of the boilers were burning pulverized fuel, the other two using sawdust, as described in the article, but Lopulco equipment has been supplied to be used with all four boilers, if necessary.



General Types of Fuel Economizers



HIGHER STEAM PRESSURES AND TEMPERATURES HAVE CREATED AN INCREASED DEMAND FOR ECONOMIZERS. BY W. F. KEENAN, JR.*

ECONOMIZERS are used to transfer heat in exit flue gases from boilers to boiler feed water. Heat that would otherwise be wasted is thus returned to the boiler and more steam is generated for the same weight of fuel burned, or for the same amount of steam generated less fuel is required. Economizers in some form have been used for more than 75 yr., but for reasons which will be indicated later, much greater general interest has been shown in them during the past 5 yr. than at any other time in their history.

Formerly, in practically all cases, economizers were installed so that all of the gases and all of the feed water for a group of boilers were handled in one economizer. Under particularly favorable conditions, as in cases where a plant has been especially designed for the group or house type economizer, or where, for other reasons, the unit type cannot be advantageously applied, the former is still used; but the great majority of economizers now being installed are of the unit type in which one economizer handles the gases and feed water for one boiler only. Some of the reasons for this may be summarized as follows:

SINGLE UNITS HAVE MORE ADVANTAGES

Serving two or more boilers, the group type economizer must ordinarily be located at a considerable distance from one or more and, in some cases, from all of the boilers. A large flue must be constructed between boilers and economizer, and this flue must be well built and well insulated to minimize losses due to infiltration of air or radiation of heat from gases in transit to the economizer. Such a flue, however, no matter how well constructed or maintained, will be subject to more air infiltration and greater heat losses than a short direct connection from a boiler to a unit type of economizer.

When any one of the boilers served by a group economizer is out of service, there is likely to be considerable air infiltration through the dampers for closing off that boiler since such dampers are rarely, if ever, gas tight. In addition, with a group economizer, it is necessary to install by-pass dampers to permit operation of the boilers when the economizer is not in service, or when the total weight of flue gas is greater than can be handled by the economizer. Such dampers introduce additional possibilities for air infiltration.

In most cases the group type requires more floor space than the unit type and, when this is considered in connection with added costs and less efficient operation, as previously described, it is not surprising that the unit type is now generally preferred. Other factors in the shifting of favor to the unit type are:

First, with the group type, when the economizer is out of service, the performance of every one of the boilers to which it is connected is affected, while a modern unit type can be kept in service whenever corresponding boilers are in service and work can be done on it whenever the boiler of that unit is down for other purposes.

Second, even with the increased size of boiler units now in vogue, the size of the unit type is such that the outer casing and other costs incidental to each separate economizer unit do not prohibitively increase the total cost of installation per square foot of economizer surface.

INDUCED DRAFT NEEDED FOR BEST RESULTS

Economizers can be designed for operation with natural or induced draft. In earlier days natural draft was used in most cases, but today, natural draft installations are rare. One reason for the infrequent earlier use of induced draft was that the fans and driving equipment had not then been developed to present high standards for reliability, power consumption and variable speed control. There was a natural and well justified inclination on the part of capable operators to rely on a good sized stack to carry the load rather than on a piece of machinery in the boiler room that might or might not be operating when most needed. Due to poor furnace conditions and lower overall efficiencies then prevailing, gas weights and temperatures to induced draft fans were higher per pound of steam generated than they are today and, also, by greatly increasing the size of fans and amount of power required to drive them, this made the use of induced draft unattractive.

Today, the use of induced draft is almost essential. Design and construction of fans, driving motors and speed control devices have been so improved that this equipment is now highly efficient and thoroughly dependable. Improved furnace conditions and higher overall efficiencies have greatly reduced the amount of excess air and weight of gas which fans must handle.

For typical modern central station operation it can be shown that the power required for the fan motors to produce 1 in. of induced draft is equal to the generated power resulting from an increase of 2 deg. in the feed water temperature produced by the economizer. Furthermore, gas temperatures leaving economizers or other final heat recovery apparatus are now so low that it would be impossible to operate on natural draft. From all angles,

*Chief Engineer, Power Specialty Co.

therefore, the use of induced draft is now not only permissible and proper, but desirable and a practical necessity as well.

The great revival of interest in economizers shown during the past 5 yr. may be ascribed to:

1. Increased fuel costs which have created a general demand for all types of fuel-saving equipment.
2. Increased steam pressures and the resulting higher saturated steam temperatures which have increased flue gas temperatures and lowered boiler efficiencies proportionately.
3. Improvements in design, increased reliability, and increased efficiency of induced draft equipment.
4. Development of reliable and efficient unit types of economizers.

According to the old-fashioned idea, an economizer was something to be installed in the path of the flue gas to pick up enough heat to justify its use, but not enough to lower the temperature of the gas to the point where the resulting natural draft would be insufficient for boiler and economizer. Formerly, at any combustion rate, the ratio of gas to steam weight was high and the loss of heat to the stack in proportion, so that a satisfactory water temperature rise could be obtained without much loss of gas temperature. Under these conditions a comparatively high mean temperature difference between gas and water was realized, which compensated for low rates of heat transfer due to low rates of gas flow and kept surface requirements within bounds.

Economizer More Efficient Than Last Passes of Boilers

With present-day low ratios of gas to water weights (1.3 to 1.5), the loss in temperature on the gas side must be about three times the increase in water temperature, and for high inlet water and low inlet gas temperatures, this reduces the amount of work that can be done per square foot of economizer surface. As a rule, however, the temperature of water entering the economizer is 150 deg. or more below the temperature of steam and water in the boiler, and as a result of this and of the counter current flow of gas to water in best modern designs, the economizer is a more efficient gas cooler than the heating surface in the last passes of a boiler, where the water is practically at saturated steam temperature, and there is no counter current effect to increase the mean temperature, and where rates of gas flow are relatively low and rates of heat transfer per degree mean temperature difference are also low on that account.

The ratio of gas temperature drop to total temperature difference between the inlet temperature of gas and water will be constant regardless of how these temperatures are varied if the weights of gas and water are constant. For instance, if the inlet gas temperature is 650 deg. and the outlet temperature 350 deg., while the inlet water temperature is 200 deg., the ratio of (650—350) to (650 — 200) or 0.67 to 1 will be maintained so long as gas and water weights are unchanged. If the size of boiler is reduced so that gas enters the economizer at 750 deg. instead of 650 deg., the gas drop will be $0.67 \times (750 - 200) = 367$ deg., and the outlet gas temperature will be 383 deg. In other words, if the gas temperature entering the economizer is increased 100 deg., the gas temperature leaving will be increased only 33 deg.

In a case like this it would be possible to reduce the size of boiler considerably and of the 100 deg. lost by so doing, 67 deg. would be regained in the economizer. If it were desired not to increase the temperature leaving economizer, the required economizer would have a gas-water ratio of $(750 - 350) \div (750 \times 200) = 400 \div 500 = 0.73$ to 1. The increased economizer surface required to obtain this ratio would be considerably less than the amount of boiler surface omitted in order to provide an increase of 100 deg. in the temperature of the gas leaving the boiler.

Economizers Save Fuel and Increase Boiler Capacity

Briefly summarizing the merits of economizers, we find that they will save fuel by cooling the flue gas well below the temperature possible with a boiler only, provided the feed water temperature entering the economizer is well below steam and water temperature in the boiler; they will reduce flue gas temperatures more effectively than the heating surface in the cool end of the boiler and will reduce the total heating surface required for a given outlet gas temperature; their effectiveness is limited by the temperature differences between saturated steam in the boiler and the entering feed water. Feed water temperature leaving the economizer should be 25 to 50 deg. below that of the saturated steam.

In addition to saving fuel or reducing heating surface, economizers increase boiler capacity. For example, if the work done in an economizer is 10 per cent of the total work in boiler, superheater and economizer, the boiler unit so equipped produces 10 per cent more steam for the same weight of fuel burned. In a plant having 10 boilers, the additional capacity obtained by providing 10 economizers would be equal to the additional capacity of an eleventh boiler, and the investment for ten such economizers should properly be credited with an amount equal to the first cost of an eleventh boiler plus the additional building required for it, plus necessary coal and ash handling and coal burning equipment, feed pumps, regulators and everything else that would be required to complete an eleventh boiler unit. Moreover, the overall efficiency of a plant containing 10 economizer-boiler units generating the same total weight of steam would be 8 to 10 per cent greater than the overall efficiency of a plant containing 11 boilers without economizers.

In a boiler not equipped with an economizer, overall efficiency beyond some critical rating will drop rapidly as the per cent of rating is increased, but boilers equipped with economizers will have a much flatter efficiency curve over a wide range of load.

Clean Water and Tubes Important

In economizer operation and maintenance the principal items of interest are:

1. Quality of feed water.
2. Drain and regulating valves.
3. Insulation and leakage.
4. Cleaning.

Dirty feed water will deposit scale and mud which must be cleaned out at regular intervals. Scale and mud so deposited reduces heat transfer and may accelerate internal corrosion. In economizers, as in all other steam generating equipment, time or money spent on improving the quality of entering feed water will be well repaid.

Regulating valves are best located between the economizer outlet and the boiler so that the full pump pressure is on the economizer at all times. The use of drain or blowoff valves to clean out economizers in service is unsat-

isfactory and in high water velocity economizers it is not necessary to use blowoff valves to lower the concentration of the water, since, due to the high water velocity, there is no re-circulation within and therefore no tendency to increase the concentration as in boilers.

Economizer casings and inlet gas flues should be well insulated and gas tight. To check on gas tightness, it is well at regular intervals to analyze samples of gas leaving the boiler, entering and leaving the economizer.

External cleaning is such an important economizer operating problem that cleaning apparatus and equipment should be given regular and careful attention. To check on the efficiency of cleaning it is well to keep records of gas and water temperatures and draft losses through the economizer. Any falling off in the quality of cleaning may be readily noted by an increase in the outlet gas temperature, or decreased outlet water temperature leaving the economizer, or increased draft loss through the economizer.

Economizer Operation and Maintenance

Cleanliness of Tubes and the Keeping of the Water and Gas at Proper Temperatures Are of Great Importance

PROBABLY THE MOST important point in successful economizer operation is the cleanliness of the tubes, both interior and exterior.

Because of the comparatively small difference in temperature between the gases and the water passing through the economizer, special care should be exercised to keep the outer surface free from soot and dirt, if a high rate of heat transfer is to be expected.

In some designs the outer surface of the tubes is cleaned by steam jets similar to the soot blowers for boilers. The soot-blower elements are of the rotating type, extending into the gas chamber parallel to the economizer tubes and are controlled by an external valve. Cleaning is done while the economizer is in operation and generally at the same time that the boiler surface is cleaned. These soot blowers are sometimes used with vertical tubes and are a necessity for horizontal tubes.

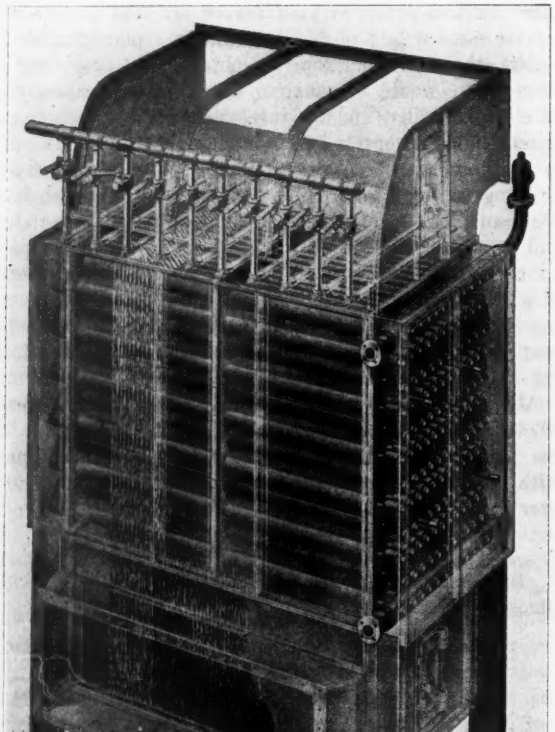


FIG. 1. THIS ECONOMIZER HAS SOOT CLEANED BY WATER SPRAYS

For good results with soot blowers, the inlet water temperatures to the economizer should be at least 180 to 200 deg. F. and superheated steam of at least 150 lb. pressure should be used by the blower. This is necessary to avoid, as much as possible, the condensation of steam on the tubes and provide sufficient pressure for effective cleaning. A certain amount of moisture in the economizer chamber is inevitable, but this should be kept at the lowest possible point to avoid serious corrosion, especially with coals of a high sulphur content.

The flue gas temperature should not be lowered below the dew point, since condensation of the vapor content may cause the soot to adhere to the tubes and render its removal costly. An average minimum is 240 deg. F.

In certain types, when the economizer is out of service, water sprays are used for flushing away the soot deposits. The washing system consists of a series of permanent spray pipes placed above the top row of each bank of tubes and transverse to them. Each group of spray pipes is controlled by a quick-opening valve conveniently located and connecting to the washing water header. This arrangement permits the easy admission of water into any spray pipe desired. Cross slots are cut in each spray pipe so that water passing through these falls directly on each of the elements in the top row and flows down over one row of tubes after another. This is illustrated in Fig. 1. The waste material is washed into cast-iron pans forming the bottom of the economizer, thence to the drain pipe.

Soot Removed by Scraping

In one well-known design of economizer with vertical tubes, the exterior surface is kept clean by an original and unique method. Each tube is encircled with a set of triple overlapping scrapers which travels continuously up and down the tubes at a slow rate of speed. As shown in Fig. 2, each of the three sections of the scraper has a beveled cutting edge top and bottom. Both these cutting edges are directed upward and the parts are so supported that these edges are forced against the tube on the upstroke, thus dislodging the soot.

The mechanism for working the scrapers is placed on top of the economizer, outside the chamber and the power is supplied either by a belt from a line shaft or by a small independent engine or motor as shown in Fig. 3. Soot

accumulations in the chamber below the economizer may be removed by mechanical conveyors or by means of vacuum systems.

Figure 4 shows a sectional view of an economizer installation with the mechanism for moving the scrapers up and down the tubes. The counter-current principle of the gases and water traveling in opposite directions is shown by the arrows.

Periodical Inspection and Cleaning Necessary

Economizers are often placed in inaccessible places and receive practically no attention. Dirt and dust frequently accumulate so thick on top of the economizer that it cannot be seen and it is generally safe to say that the condition of the tubes has been neglected also. In some cases, leaks have developed and water run into the economizer chamber resulting in serious corrosion and eventually in the loss of some part. Some breakage of parts is to be expected, but this trouble may be reduced materially in many cases by a little more care and attention.

Thorough inspections at regular intervals by a competent inspector are advisable and, if these are made and defects remedied, many annoying troubles will be avoided.

Occasional Explosions Due to Vapor Pressure

Economizer explosions have been few in proportion to the number of installations. The wreckage is generally so complete that it is difficult to determine the real cause and even experts do not agree. Probably the majority of explosions have been the result of the outlet valve becoming closed in some manner, thus making a closed vessel of the economizer, and allowing the flue gas to generate steam pressure. Also in some cases gas explosions have wrecked the economizer. In these cases, combustible gases resulting from incomplete combustion of fuel have accumlated in the economizer and were then fired by a spark passing through the setting.

The principal economizer troubles are broken tubes and headers. Occasionally a bend breaks, but ruptures here and in the manifold pipes are rare. The causes of broken tubes or headers are varied and sometimes difficult to determine, but the majority of them will come under one of

FIG. 2. HERE A SOOT SCRAPER ENCIRCLES EACH TUBE AND IS DRAWN UP AND DOWN MECHANICALLY

the following: (1) defective casting; (2) inaccurate machine work; (3) rough handling in shipment or before erection; (4) unequal expansion and (5) water hammer. The manufacturer controls the first two and troubles due to these causes are infrequent. The third is more common than might be expected and is hard to control, especially where the sections are unloaded and handled by inexperienced persons. The fourth and fifth are the result of improper installation or erection.

Cast Iron or Steel Tubes May Be Used

Until about 10 yr. ago, pressures were comparatively low and economizers were designed for a relief-valve pressure of 250 lb., with the majority of installations operating

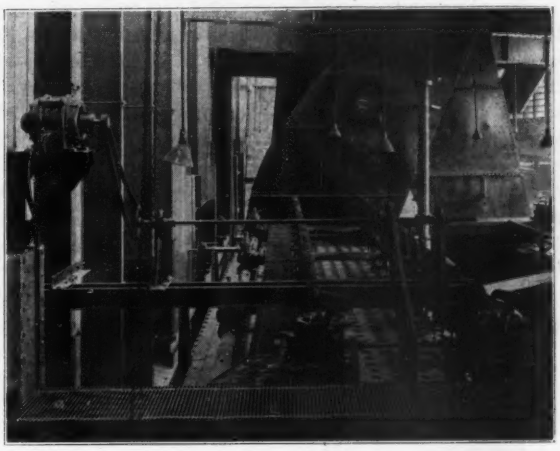


FIG. 3. A SMALL MOTOR DRIVES MECHANISM FOR OPERATING THE TUBE SCRAPERS

well below this pressure. Pressures gradually increased to such an extent that changes in design became necessary, particularly in the methods employed for fastening the tubes into the headers. As a result, several designs of patented joints have been developed.

These permit the use of cast-iron economizers up to a relief-valve pressure of 450 lb., with a factor of safety of at least six in all parts. Cast-iron economizers are used for working pressures as high as 400 to 450 lb. per sq. in. but the cost increases rapidly with an increase in pressure above 250 lb.

In some cases, where cast-iron economizers are used, a method of solving the high-pressure problem is to install dual pressure pumps so that the economizer pressure may

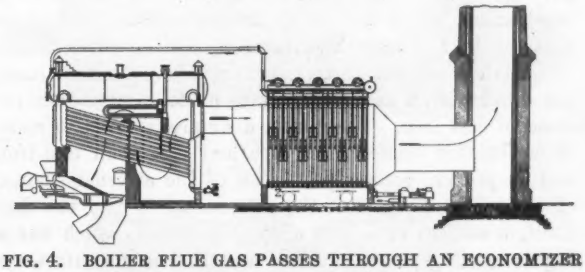


FIG. 4. BOILER FLUE GAS PASSES THROUGH AN ECONOMIZER BEFORE REACHING THE STACK. MECHANICAL SOOT SCRAPERS OPERATED BY CHAINS

be kept below 250 lb. and the water, after passing the economizer, goes to the high-pressure stages of the pump, where it is raised to full boiler pressure. This arrangement reduces the amount of high-pressure piping and fittings required, although some extra piping is required to bring the water back to the pump, which is considered by some engineers to be a serious objection.

Several designs of economizers are now using steel tubes. Cast-iron will resist corrosion better than ordinary

steel but will not stand as high a pressure. On account of its strength, however, steel is demanded in high-pressure installations and today, in nearly all modern installations, for pressures varying from 400 to 1200 lb. per sq. in., the economizers are of steel tube construction.

Factors Involving Tube Corrosion

By observing certain precautions, corrosion in steel-tube economizers may be reduced to a minimum as low as with cast-iron. Water entering the economizer should have a temperature at least equal to that corresponding to the dew point of the gases to prevent external corrosion and, in case the water is not deaerated, the temperature should not be less than 180 deg. to prevent internal corrosion. With properly degasified water, inlet temperatures as low as 120 deg. F. have worked out satisfactorily, but the exact temperature is dictated by the station heat balance.

With hard feed water, the formation of scale within the tubes may seriously affect the efficiency of heat transmission and the cost of cleaning may prove excessive. Also frequent turbining wears the tubes and the vibrations often cause leaky joints.

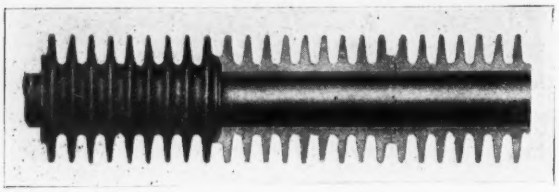


FIG. 5. EXTERNAL SURFACE OF THE STEEL TUBE IS PROTECTED BY CAST-IRON RINGS

To protect against external corrosion, one manufacturer uses cast-iron sleeves or rings outside the tubes. As shown in Fig. 5, the ends of these ring castings are faced with male and female joints to insure the complete protection of the steel tube and to protect only the cast-iron covering to the furnace gas. This extended surface, having a decidedly greater outside area per unit of length than any base tube, requires a minimum space and permits of a construction much less bulky than that which could be obtained by any smooth surface.

Another manufacturer, working along similar lines, has developed an extended surface made of steel discs instead of cast iron. These steel discs are believed to make closer contact between the pipe and disc than cast-iron and so provide greater protection of the external surface of the tube. To protect the external surface of the disc itself, a surface of a lead alloy is provided, which has a higher melting point than lead alone. This manufacturer also provides a coating of the same alloy on the inside of the tube to prevent internal corrosion.

As previously stated, if an economizer tube is at a temperature below the dew point of the flue gas, condensation will occur. The dew point of the gas depends upon the moisture content per unit volume of gas. It has been generally established that any economizer unprotected against corrosion would suffer disastrous results, if the temperature of the feed water was not greater than 180 deg. F. Below this temperature, corrosion works both from the inside and the outside on unprotected surfaces, for the reason that sulphurous acid is formed on the outside of the tube and, on the inside, water at this temperature has a capacity of carrying 3 cubic centimeters of oxygen per liter.

As it is known that anything in excess of 0.2 cubic centimeters of oxygen per liter of water is destructive, it may be readily seen that either the water must be thoroughly deaerated or a protective coating of the tube must be provided.

The velocity of gas through the economizer should be the highest practicable, as this motion tends to clean soot from the tubes and, in addition, the scrubbing action is useful in increasing heat transfer.

Reasonably high water velocity also increases heat transfer, sweeps air bubbles away from the inside tube surface and causes a better cleaning action on the inside of the tube.

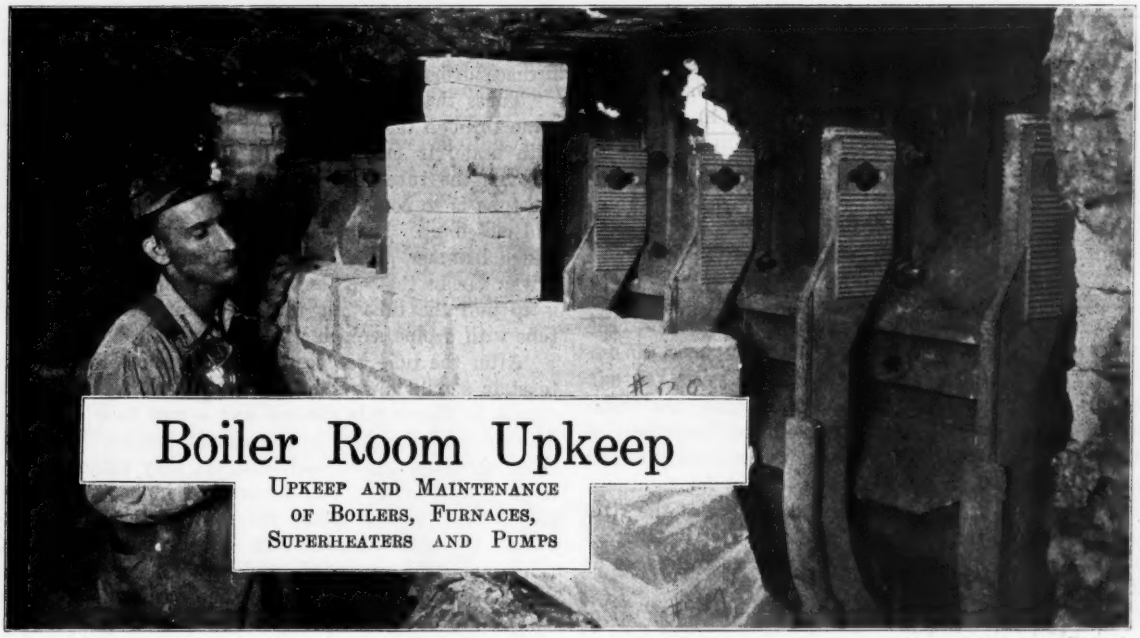
Cost of Power in Industry

While it is generally known that power is but a small part of the cost of production for many kinds of manufactured goods, it is interesting to have the results of a study made by H. N. Wood of the Pennsylvania-Ohio Power and Light Co. as to the actual percentage which power cost is of total cost. The figures are as follows:

For steel fabrication, 0.066 per cent; for shoes, 0.5 per cent; bakery products, 0.68 per cent; tanks, tank cars and steel barrels, 0.81 per cent; stoves, 1.00 per cent; flour mills, 1.00 per cent; veneer mills, 1.18 per cent; small rubber tires and tubes, 1.35 per cent; heavy tires, 1.5 per cent; leather tanning, 1.5 per cent; iron foundries, 1.85 per cent; stone quarry, 2.8 per cent; steel billets, slabs, sheet and bars, 3.0 per cent; milk stations with refrigeration, 3.2 per cent; ice plants, 26 to 33 per cent; small motors and generators manufacturing, 0.3 per cent; auto springs, 0.405 per cent; printing, 0.42 per cent; lumber, 0.44 per cent; steel castings, 3.05 per cent; brick, 4.9 per cent.

Evidently the survey is not complete, but it is a start and further data should be added by those interested in the industrial power problem. While the figures would seem to indicate that the power problem is of little consequence as affecting the cost of products, it is to be remembered that, in many of the industries not given in the present data, this cost is much larger than the values shown, also that any saving in power cost is a gain which goes directly to the profit side of the business, as there is no offsetting expense or reduction in income to be charged against the saving.

In September the average daily production of electricity by public-utility power plants was 179,500,000 kw-hr., 3½ per cent larger than the average output for August and 12 per cent greater than the output in September, 1924, according to the U. S. Department of the Interior. The total output of electricity by public-utility power plants in the United States from January to September, inclusive, in 1925 was 47,570,000,000 kw-hr., a general increase of 10 per cent over the same period for 1924. The output by the use of water power for the same months was 16,548,000,000 kw-hr. for 1925, also an increase of 10 per cent over the same period for 1924. The total capacity of generators in electric public-utility power plants in January, 1924, was 19,400,000 kw.; in February, 1925, the total capacity was 22,500,000 kw., an increase of over 3,000,000 kw. or about 16 per cent in the 13-month period.



Boiler Room Upkeep

UPKEEP AND MAINTENANCE OF BOILERS, FURNACES, SUPERHEATERS AND PUMPS

IN A BOILER operating with absolutely pure, non-corrosive water and over a furnace in which the combustion of the fuel was perfect, it would never be necessary to clean the tubes; they would always be bright and free from scale. In practice, unfortunately, we do not always get pure water and combustion is seldom perfect; consequently, it is customary to resort to periodic cleaning. Modern water treating equipment, however, has done much to lessen troubles due to scale formation and in certain plants the boilers operate as long as a year at a time without cleaning. Even then, practically no scale is found.

Where the water contains scale-forming impurities, the periodic removal of scale from the boiler tubes is an extremely important item on the boiler room program. The tubes are the very heart of the boiler and unless they are kept clean and free from scale, efficient transfer of heat from the furnace gases to the water will not be obtained.

Tube cleaners are manufactured in a variety of types and sizes and are either air, steam or water-operated. They consist usually of some form of turbine head or motor to which is attached a number of cutters or knockers, depending upon whether the cleaner is to be used with water-tube or fire-tube boilers. In fire-tube boilers the scale forms on the outside of the tubes and the vibration method of cleaning is used. For this purpose, a vibration head is attached to the air or steam-driven motor, which, when rotated at high speed, sets up local vibration which effectively jars loose the the inelastic scale formation from the outside of the tube.

For cleaning the inside of water tube boilers, the motor is fitted with a cutting or scraping head which actually cuts or scrapes the scale from the tubes. Once the scale is loosened, the air, steam or water used to drive the motor carries it out of the tube. Steam, however, is not to be recommended for driving cleaners in those types of boilers where the operator has to enter the drums for cleaning, because of the possibility of scalding due to bursting of the operating hose. Vibration type cleaners for return tubular boilers are driven only by steam or air pressure, as it is impractical to operate a water-driven cleaner with this type of boiler.

In operating tube cleaners, let the cleaner enter the tube just as fast it will cut its way, but do not attempt to force it through as this will only damage the machine and cut down its speed. Let it remain in one place until all the scale is removed, allowing it to work its way gradually into the tube and moving it back and forth as may be needed to relieve the head in thick scale. The operator will learn after a little experience to feel just what the cleaner is doing. Care should be taken, when the machine reaches the lower end of the tube, to prevent the cutting head from passing out of the tube, as it can be severely injured in doing this. The cleaner should be watched during the cleaning of the first tube and when the head reaches the lower end of the tube, a mark can be made on

FIG. 1. TUBE CLEANER FOR THE REMOVAL OF SCALE IN A WATER TUBE BOILER

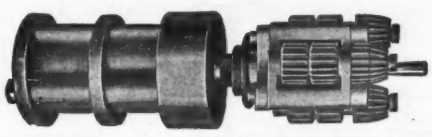


FIG. 2. VIBRATOR TYPE OF SCALE REMOVER SUCH AS IS USED IN FIRE TUBE BOILERS

the hose so that in cleaning the other tubes the operator will know when the cleaner is through the tube.

Boilers should be withdrawn from service at least once a month and given a thorough inspection inside and out. After all the tubes have been cleaned from scale and the exterior surfaces thoroughly brushed off, they should be inspected for pitting and corrosion. The water side of the

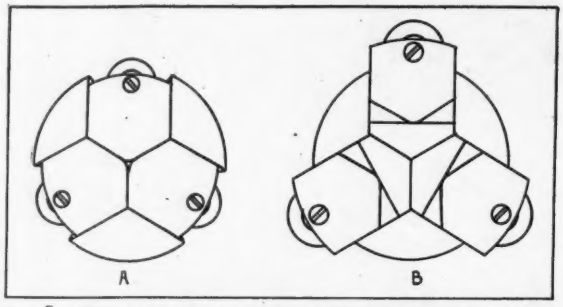


FIG. 3. END VIEWS OF A TUBE CUTTER A, WITH CUTTER ARMS DRAWN IN. B, WITH CUTTER ARMS EXTENDED

shell also should be carefully examined near the water line, as pitting is often more pronounced here than at other parts. In boilers having stays, it is necessary to test for tightness of stay rivets. To test a rivet for tightness, place the thumb and finger so as to rest against the rivet head and the surface around it. Then hit the rivet with a hammer. Any relative motion of the rivet and plate can be felt.

If any tubes are found to be in a dangerous condition, they should be replaced immediately. Renewing a tube is one of the most disagreeable jobs around the boiler room and it is essential that the right tools be available. The simplest way of removing a damaged tube is by means of a tube cutter. This consists of a body carrying the cutters, attached to a shaft fitted with a guide and handle. By rotating the head inside the tube, the cutters press into the walls and gradually cut it off inside the tube sheet.

Another way of removing a tube is by means of a ripper. This is a simple tool, something on the order of a chisel, by means of which the tube is ripped through its seat. The tube can then be collapsed and the ends drawn

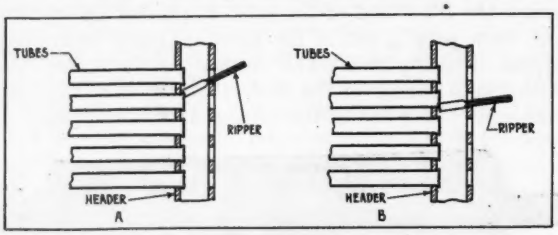


FIG. 4. SKETCHES SHOWING RIGHT AND WRONG METHOD OF REMOVING A TUBE WITH A RIPPER. A. RIGHT METHOD. B. WRONG METHOD

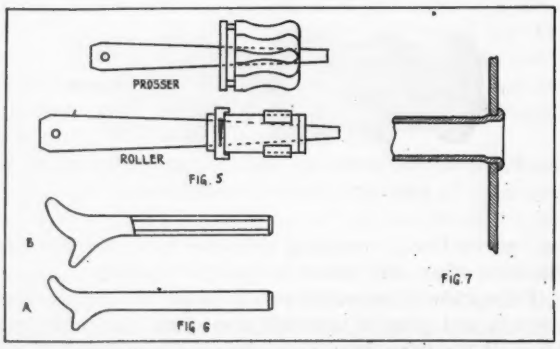


FIG. 5. WEDGE AND ROLLER EXPANDERS
FIG. 6. BEADING TOOLS
FIG. 7. SECTION SHOWING BEADING OF TUBE ENDS

through the tube sheet. To remove the tube, cut it up into short lengths and remove the pieces through the furnace doors.

Tubes that cannot be taken out at the manhole must come through the tube hole. As tubes are usually covered with scale, it may save time to run the tube cleaner through the tube first to knock off all the scale. When the tube is to come out in this way, the ends are ripped and closed up. It may be driven out a few feet with a sledge hammer and a block of wood, but it cannot be driven far in this manner. Perhaps the simplest method is to pull the tube out with a chain host, twisting the tube with a pipe wrench while pulling.

After the tube has been removed, which it is needless to state should always be done with great care, the seat should be thoroughly cleaned and a new tube slipped in. The tubes of fire tube boilers should project through the sheet about $\frac{3}{8}$ in. on each end. If they extend through more than this they may be cracked in heading. In expanding the tube in place, the expander should be set to extend the same distance each side of the sheet and the tube should be expanded gradually all around. A tube may be rolled out too thin and thus be made excessively thin at the seat. Care should be taken to avoid this. When a tube is rolled out tight all around, the rolls will be running on a smooth surface, and the plug will be tight when tapped with a hammer. It is best to stop at this time and examine if there are any spots that are not rolled out tight against the seat. After the tubes have been rolled in, the ends must be beaded by means of a beading tool.

Patches, Hard and Soft

In considering the practice of patching, it must be obvious to anyone having to do with boilers that patches should only be applied as a last resort.

There are two kinds of patches—soft patches and hard patches. A soft patch is always a temporary repair; in fact, it should be nothing else, for due to the method of its application, the expansion and contraction of its integral parts are of such variance that leakage, except under constant vigilance, is bound to occur. A soft patch derives its name from the fact that a rubber gasket or cement is employed to make a tight joint between the patch and the defective plate. The edges of the plate are not calked. It is in reality a packed flange joint.

Because of its construction, a soft patch is not applicable to that part of a boiler which comes in direct contact with the products of combustion. Consequently, it is not feasible except upon the external shell of internally fired boilers and above the fire line in the steam space of horizontal tubular externally fired boilers.

In making a soft patch, proceed as follows, assuming the defect to be on a curved surface. Secure a piece of boiler plate of the required thickness, cut it to size and bend carefully to conform to the surface of the defective plate. The proper size and number of cap screws must next be determined and, if possible, the holes drilled through the patch and the plate with the patch in position. This insures alinement and obviates the use of a drift pin. The remainder of the operation consists of inserting the gasket and bolts and screwing down, being sure to "follow-up" the bolts or cap screws, as the case may be, as the boiler warms up.

A hard patch differs from the soft patch only in application. No gasket is used, the edges being beveled and

calked instead and rivets used in place of cap bolts or bolts and nuts for securing the patch to the defective plate. A patch properly applied and completed in a workmanlike manner is in no way detrimental to a boiler except insofar as the allowable boiler pressure may be decreased.

In many cases, however, patching is not feasible, particularly where the crack or whatever the nature of the defect may be is located in a corner, or where there is a difference in expansive movements of the sheets involved. In such cases an entire new sheet is necessary. In removing the defective sheet, great care must be exercised to avoid damaging the rivet holes in the adjacent sheets.

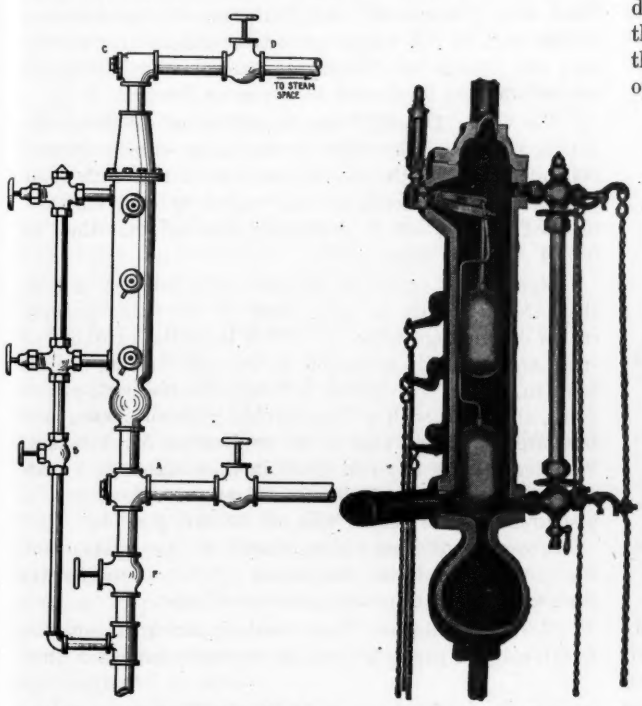


FIG. 8. PROPER METHOD OF CONNECTING A WATER COLUMN

FIG. 9. ALARM TYPE OF WATER COLUMN

screw the bonnet ring. (2) Remove the trimmings from the body and insert a pin or wire through the groove in the disc locknut and the drill hole in the stem. (3) Apply a suitable abrasive compound to the seating surface of the disc. (4) Replace the trimmings in the body with the disc resting upon the seat and with the projection on the bottom of the bonnet within the neck of the body, but with the bottom of the flange on the bottom separated from the top of the neck by from 1/16 to ⅛ in. By holding the bonnet stationary and turning the spindle, the proper relative position of the bonnet and disc may be readily secured. Grinding is accomplished by turning the disc back and forth on the seat and occasionally changing the position of the disc. When sufficiently ground, remove the trimming, clean the seating surface and repeat the operation using oil instead of an abrasive.

Safety valves should be tested at regular intervals to

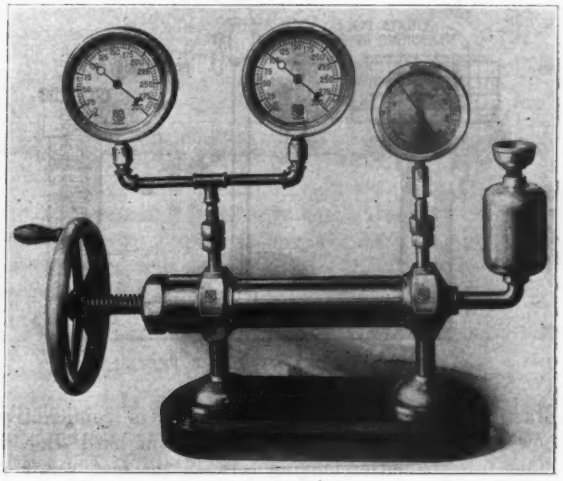


FIG. 10. GAGE TESTING OUTFIT

Valves should never be permitted to leak. This, of course, applies to all valves, but particularly to those valves in the plant which are normally closed, such as the blowoff valve and the safety valves. When it is considered that a ½-in. diameter stem leaking all around the stuffing box will blow about 40 lb. of steam an hour with 100-lb. pressure on the valve, it is apparent that leaky valves should be repaired as soon as possible.

Sometimes leaks in valves are due to distortion of the valve seat caused by the weight of piping carried by the valve. There should be supports near all valves. In some cases valves are seriously strained when being assembled into the piping by carrying the twist through the body of the valve.

If a leaky valve stem cannot be made tight by a moderate amount of screwing, the packing should be renewed at once. The need for renewing packing is not always indicated by leakage. Many times it is indicated by the position of the packing nut or sleeve.

Where the service is of such a nature that regrinding is likely to be necessary, it is advisable to install valves of the "regrinding" type. If a valve of this type leaks, it may be made tight in the following manner: (1) Un-

determine whether they are in good operating condition. This may be done, either by raising the steam pressure in the boiler to such an extent that the valve pops off in its normal manner or by a hand lifting attachment, whereby the valve is raised from its seat mechanically. The former method, of course, is the most effective, but it has the disadvantage of being wasteful. The hand lifting method is used more frequently than the pressure method, some engineers specifying that the valve should be tested once a day.

If, when testing the safety valve, it is found that the popping pressure is incorrect, the valve must be readjusted. The method of doing this will, of course, depend largely upon the design of the valve. As a general rule, the procedure will be somewhat as follows: First, remove the cap and lever. Then loosen the check nut on the compression screw and adjust the popping pressure by turning the screw either to the right or left, according to whether the pressure is to be raised or lowered. Turning it to the right will raise the popping point, while turning it to the left will lower it. A quarter of a turn of the compression screw will change the popping point 5 to 10 lb. The check nut is then tightened and the valve

blown to determine the result. When the correct setting is obtained, the cap and lever should be replaced.

In order to adjust the amount of blowdown, the hexagonal head lock screw in the side of the base casting must be removed. With a sharp pointed tool inserted through the opening, it is then possible to turn the notched huddling ring, a right-hand rotation decreasing the blowdown and a left-hand rotation increasing it. Be careful to replace the lock screw before blowing the valve.

What has been said in regard to leakage of valves applies with particular emphasis to safety valves. Safety valves usually are adjusted at the factory for the proper blowdown and are ground in while hot, so that the seat will be formed with the part of the valve as near as possible the temperature at which they will operate in actual

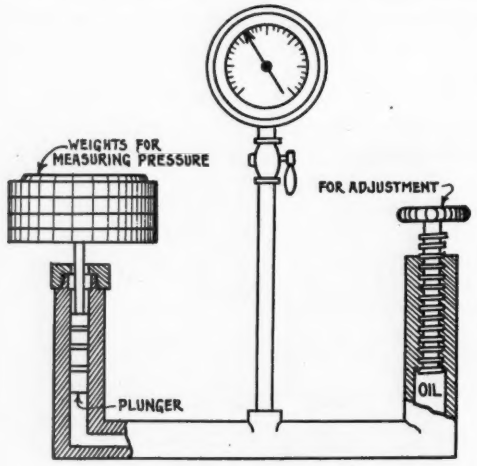


FIG. 11. DEAD WEIGHT TESTER

practice. Leakage often occurs, even in comparatively new valves, due to metal chips, pieces of hard scale and other foreign matter lodging between the seat, scratching and denting the surfaces of the valve and seat. The remedy for such leakage, of course, is to regrind the valve.

Regrinding can, in most cases, be accomplished without removing the seat bushing from its valve base, but should only be done by a competent man.

Care of Gages

Although simple in construction, the water gage glass and water column is an extremely important part of the boiler and, unless maintained in perfect operating condition, may endanger the safety of life and property. In small installations, the gage glass is sometimes connected directly to the boiler, but it is more usual to connect it to a water column. For small boilers, the connections to the column should never be less than 1 in. in diameter, while for large boilers the minimum should be 1½ in.

The proper method of piping up a water column is shown in Fig. 8. From the top of the boiler a pipe is connected to the upper part of the boiler or the steam space. From the cross A the water connection enters the boiler and a bottom connection used as a blowoff line leads to the ashpit. Ordinarily, as sent from the manufacturer, the water glass is fitted at the lower end with a petcock. It is good practice to remove this and connect in a nipple and a valve B, since the opening in the valve is larger and provides a freer discharge. As shown, this line is connected into the blowoff line from the water column.

Valves are usually inserted in the steam and water lines to the column at the points D and E. These valves are of considerable advantage in clearing the water connections of foreign material that may accumulate therein. If these valves are not installed and the valve F is opened, there is no certainty that most of the blowing out is not done through the steam connection. The more clogged the water connection is, and therefore the more it needs cleaning, the less likely it is to be cleaned under such conditions. With the column piped as in Fig. 8, the water connection may be blown separately and, therefore, more effectively. To do this, close valve D and leave E open. Then, when F is opened, full boiler pressure is concentrated on the area of the water connection and the connecting pipe and fittings are thoroughly washed out. The steam connection may be cleared in the same manner.

The valves D and E are usually gate valves of the outside screw and yoke type or stop cocks with levers permanently fastened thereto and marked in line with their passage. In some localities such valves are not only demanded by law, but it is further specified that they be *locked or sealed open.*

Gage glasses should be handled with extreme care as they are as fragile as eggs. One of the most common causes of breakage while in service is in the existence of small cracks hardly noticeable to the eye. Letting a glass come in contact with metal, holding it in the hand at one point, cutting it with a file or laying it on an uneven surface are all things said to be responsible for breakage. Whether there is any real truth in these claims is a matter open to conjecture, but to be on the safe side it is best to handle the glasses with all the care possible.

In service, the gage glass should be blown down and the gage cocks tested frequently. Some operators try the gage cocks as often as once every 15 min.

Alarm columns are water columns which, in addition to carrying the gage glass and the try cocks, are often fitted

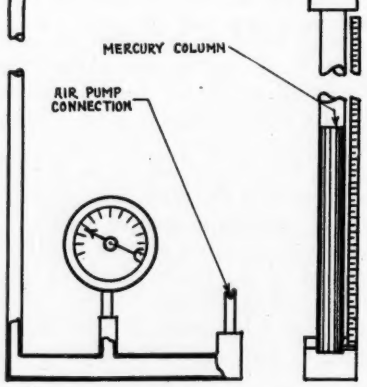


FIG. 12. VACUUM GAGE TESTER

with a signal of some sort, usually a steam whistle which comes into action at either extreme high or low water. This signal should be tested frequently, as it is usually float operated and is subject to the limitations of any float-operated device. The proper functioning of the safety signal and the entire float mechanism may be tested by opening the valve in the drain pipe below the column, per-

mitting the water in the column to escape, causing the float to fall and operating the alarm.

Care of Steam Gages

Care of steam gages consists largely in keeping them in accurate adjustment. For testing there should be available a standard test gage or, better yet, a gage-testing outfit. This consists of a hand pump for producing hydraulic pressures up to 1000 lb. or higher, fitted with a highly accurate test gage. This form of tester is shown in Fig. 10. In using this equipment, the gage to be tested is fitted to the pump and the pump cylinder filled with water or other suitable liquid. Then, by means of the hand wheel, the pressure can be raised and the gage compared with the standard.

If it is found on test that there is a practically constant difference between the readings; for instance, the operating gage may read approximately 5 lb. high over the full range of readings; this may be corrected by removing the hand of the operating gage and setting it back by the amount of the difference. If, however, the difference in reading between the operating gage and the master gage varies materially over the range of readings, the gage needs the attention of an expert and should be sent back to the factory for adjustment. It may, in fact, have outlived its usefulness.

Another form of tester is known as the dead weight tester, the principle of which is shown in Fig. 11. The constants of this apparatus are the area of the plunger and the actual weight of the test weights from which may be figured the actual pressures produced by them. Its operation is apparent from the illustration.

Vacuum gages are tested in the same manner as pressure gages; that is, by means of a standard vacuum gage mounted in parallel with the operating gage or, as shown in Fig. 12, by means of a mercury column. The mercury column method is somewhat cumbersome, but it gives a high degree of accuracy.

In the boiler room, where a rapid means for testing gages is desirable, the arrangement for testing gages by comparison, shown in Fig. 13, is convenient. The standard gage may be connected permanently at some point along the wall.

Steam pressure gages should always be provided with a siphon and a cock or valve between the siphon and the branch tee, otherwise the Bourdon tube will harden in time and become inaccurate.

Blowing Down

Practice in regard to blowing down the boilers varies largely with conditions existing in the plant and it is difficult to formulate any hard and fast rules. True, before the extensive use of feed water treating plants, making use of separators, deaerators and various chemical processes, the water in the boiler contained many impurities and as the concentration of salts and scale-forming impurities increased, due to the gradual evaporation of the water, it was necessary to blow down the boiler at frequent intervals and it is to this condition that we owe such rules as "Blow down your boiler, one or two gages once every 8 hr. or 12 hr. or 24 hr.," as the case might have been. While such rules are still applicable in many plants, there has been a tendency lately to operate the blowoff valves less frequently than in former times. In many plants, the times and amounts of blowdown are determined entirely by the condition of the water of the boiler. If, on test, the concentration is shown to be higher than that permissible, the boiler is blown down; if it is not, the blowoff valves are not opened, and the boiler is operated until such time as the concentration reaches the permissible limit.

Where the water contains no appreciable amounts of scale-forming impurities, the purpose of blowing off is first, to get rid of mud or sludge in the bottom of the boiler or in the special mud drums of water tube boilers and second, to get rid of oil and scum at and near the surface of the water. The former is accomplished by means of the bottom blowoff valves and the latter by means of the surface blowoff.

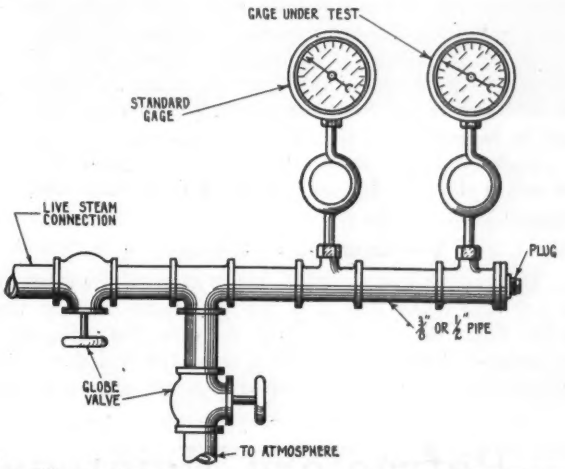


FIG. 13. ARRANGEMENT FOR TESTING GAGES IN THE BOILER ROOM

Opening and closing a blowoff valve should be done slowly and cautiously; yanking the blowoff open or closed is dangerous. This applies not only to the blowoff valves, but to any high pressure steam, water or air line in the plant. The sudden impact of high pressure steam on the piping system when a blowoff valve is suddenly opened may result in bursting of the line.

Boilers should be blown down, preferably when the circulation of the water is not rapid. If the boiler is banked over night, it should be blown off before starting up in the morning. If the boiler is operated continuously, it should be blown when the load is comparatively light.

In blowing off a boiler, considerable heat is lost. To avoid this heat loss and at the same time to improve water conditions in the boiler, systems of continuous blowdown have been developed. With this system, instead of sending the blowoff water directly into the drain, a relatively small quantity of water is caused to leave the boiler continuously from its lowest point. This water cools in giving up its heat to the feed water in a feed water heater of ordinary design and the mud which it contains is deposited in a trap. In cooling, it loses a certain proportion of the scale forming salts which had been retained in solution and after these have been deposited, the water is mixed with the feed water and returned to the boiler.

If the boiler has been blown down to the extent of 20 per cent of its contents in an hour, this means that its contents are renewed every 5 hr. In certain forms of continuous blowdown system the water removed from the boilers is passed through a special filter.

In another part of this article, we have already emphasized the importance of keeping the blowoff valves perfectly tight. There is always danger of a piece of scale or other foreign matter lodging between the valve and the seat of the blowoff valve and for this reason the seatless type of valve has been developed. Such valves are provided with some form of piston valve without projections upon which scale might accumulate.

That part of the blowoff line between the boiler shell and the blowoff valve where it passes through the furnace must be given particlar attention. Since the water does not circulate in this line, it does not carry away heat, and unless properly protected, overheating may result, causing its destruction. When coverings are provided, they should be such as may be removed from the pipe without disturbing the piping. In other words, it should be split. A heavy cast-iron sleeve is often provided around the blowoff line where it passes through the furnace. Regardless of how well this part of the system is protected, it must not be neglected and should receive continual inspection.

Under ordinary conditions, the blowoff valves should be locked shut, so that no one except those authorized to operate them may do so.

Emergency Repairs

If a serious leak occurs in one or more of the tubes of a fire tube boiler and it is not practicable to shut the boiler down for replacement of the tube, the tubes may be plugged temporarily. In such cases, the feed should be looked after to see that the water does not get low in the boiler while preparations are made for plugging the tubes. For this purpose, there is available a standard type or stopper, which consists of two heads or tapered plugs which make a joint within or against the ends of the tube and are held in place by a rod running through the tube, threaded at the ends and provided with nuts for holding them up to their position against the ends of the tubes. To fit such a stopper it is necessary to enter the combustion chamber to adjust the back end, but once fitted, it may be depended upon to fulfill its purpose.

Instead of using this type of stopper, plugs may be used which, while not as satisfactory as stoppers, can be fitted without drawing the fires and in an emergency prove of great value. Sometimes plugs of soft pine are used for temporary purposes. These are pushed in from the front until they cover the leak, and the expansion due to soaking with hot water is depended on to make a tight joint.

If a leak in a seam occurs, so serious that operation cannot be continued, the boiler must be cut off the line and the pressure reduced so that the joint can be calked. This can be done while the water in the boiler is still hot, but under no circumstances must it be done with pressure on the boiler.

Leaks in steam or water piping can often be stopped temporarily by covering it with a piece of soft copper or gasket material and clamped in place by a simple iron clamp. The clamp may be fitted around the pipe some distance above or below the leak, and then slid along the pipe until it is directly over the leak.

Refractory Maintenance in Boiler Furnaces

Air and Water Cooling Offer a Solution to Many High-Temperature Furnace Troubles

ONLY A COMPARATIVELY few years ago boilers were seldom or never operated above 150 per cent of rating. Furnace temperatures were lower then and, in consequence, the life of furnace refractories was much longer than today.

At present, it is not at all unusual to operate a boiler at 300 per cent of rating and furnace repairs are frequent, unless special measures are adopted to withstand the high furnace temperatures. More and more, power is being demanded at lower costs but the minimum of cost will soon be reached, if it has not been already, unless furnace maintenance costs can be reduced.

Many power plant engineers and executives, while studying modern methods of power generation with new theories and methods of combustion, have completely overlooked one of the most important parts of their equipment. A chain is no stronger than its weakest link and a boiler furnace is no more capable of saving dollars than its refractories will permit.

In many industrial furnaces where the walls must be torn down and rebuilt frequently, it is probable that fire-brick will continue to be used but, in modern boiler furnace construction, the use of ordinary fire-brick is being restricted to those parts where the temperature is less intense.

Ordinary fire-bricks, laid on top of one another and held together by some sort of cement, usually give the least satisfaction when used for side walls and bridge wall. This is not because of any particular fault of the bricks themselves, as they are probably of as good refractory material as can be had, but rather because a wall made of ordinary sized bricks has so many more joints than one made of large size tile.

Joints are the cause of most refractory troubles. Refractories generally fail first, not by melting but more often by disintegration because of the unequal expansion of the bricks and the shrinking and falling out of the mortar. Heat causes the mortar to recede, leaving the sharp edges of the brickwork unprotected. This starts spalling and cracking of the edges and in a short time the walls assume the appearance shown in Fig. 1.

Of course, walls do not always get as bad as this but they would, if repairs were not being made constantly.

Another example of poor side wall construction is shown in Fig. 2. Ordinarily furnace linings are laid with four courses of headers and one stretcher, but here there appears to be no definite method, as two rows of stretchers are together in some places. When clinker is scraped off the side walls, these rows of stretchers are much more liable to become loosened and forced out than the headers. Note the spalling and cracking.

To minimize repairs to fire-brick construction, one manufacturer has developed an interlocking wall which can be designed for solid or air-cooled construction. It can be used in side walls, bridge walls, or curtain walls. Although the main body of the wall is constructed of ordinary sized fire-brick, many of the bad effects of the usual construction are lessened by this construction. This wall

was designed to transfer the weight of the inside lining to the outside of the wall; to prevent the inside of the wall from pulling away from the outside; to make each section self-supporting; and to make it possible to anchor new brick work into the old wall properly when repairs are needed.

This wall is constructed in interlocking units which divide the inside wall into removable sections. Each unit consists of a retaining box built into the outer portion of the wall and shelf or header tile, which are anchored into the retaining box by using a tapered or wedge brick. The shelf brick project from each retaining box to the inside of the lining. Courses of regular fire-brick are laid, header fashion, on these shelf brick until they meet the next row of headers forming the shelf above.

Contrast this method with the construction shown in Figs. 1 and 2. With the interlocking wall no complete rows of stretchers are to be found anywhere, the only stretchers being those between the shelf brick. The latter forms a positive tie between the inner lining and the outside wall. By transferring the weight of the lining to the

FIG. 1. TYPICAL APPEARANCE OF SIDE WALLS IN A HIGH-TEMPERATURE FURNACE WITH ORDINARY BRICK CONSTRUCTION

outside wall, compression is relieved and the lining will stand higher temperatures before softening and, as a result, slag will not accumulate quite so readily.

Although such a wall will withstand the stresses and strains of expansion and contraction much better than the orthodox method of bonding, any fire-brick made, when heated to the temperature found in modern furnaces, will permit clinker to adhere unless properly cooled.

Air-Cooled Sectional Wall Facilitates Repairs

To meet high-temperature conditions, particularly if the fuel has a high ash content, this same manufacturer has developed an air-cooled wall as shown in Fig. 3. Here, vertical steel buckstays support horizontal steel channels and the heavy castings which are bolted to these horizontal channels form a rest for the special header or shelf blocks.

These header blocks are held in place by a tapered fire-brick which is locked tightly in position. The inside fire-brick lining of regular 9-in. fire brick is built up on these header brick, with only one row of stretchers under each row of header blocks. Ample provision is made for expansion in each section.

In the type of wall shown in Fig. 3, each horizontal section is an independent unit support by the furnace

FIG. 2. THIS WALL SHOWS POOR CONSTRUCTION. TWO COURSES OF STRETCHERS SHOULD NEVER BE TOGETHER

frame work so that repairs can be made to any section without interfering with any other section.

Nature of Refractory as Important as Air-Cooling

This type of air-cooled wall is decidedly superior to walls which are not cooled, although air cooling alone is not entirely sufficient to prevent the adherence of clinker. In Fig. 4 the walls are of a special monolithic material but uncooled and the pronounced clinker formations on the sides act as a shield to the ignition of the fuel along these sides. Whenever this happens, there are streaks of unburned or partially burned fuel along the sides. Almost

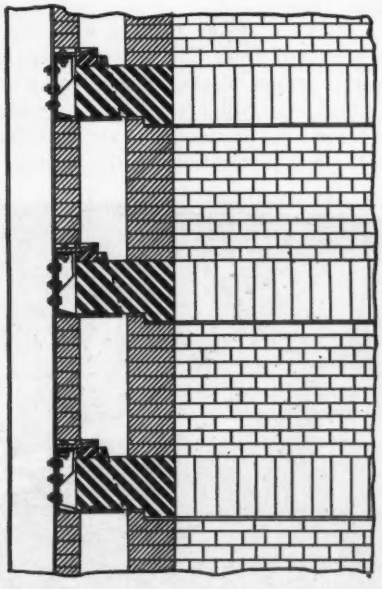


FIG. 3. THIS IS A CROSS-SECTION OF AN AIR-COOLED FURNACE WALL WITH SPECIAL HEADER DESIGN

as fast as these clinker formations are broken off, they form again.

Air cooling of the side walls, with the furnace lining of fire brick, reduces the amount of clinker formation but is not satisfactory. In certain cases, engineers sought

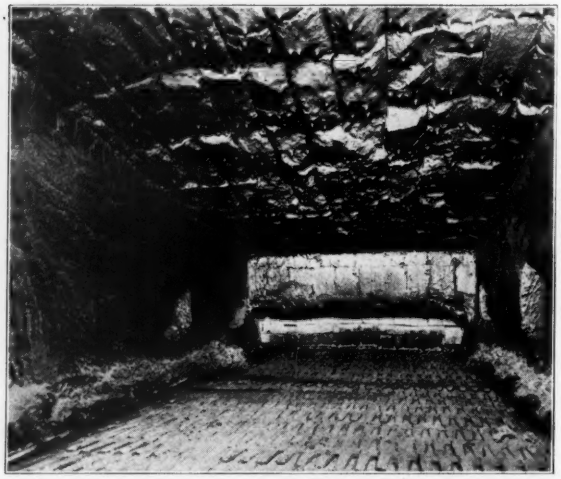


FIG. 4. UNCOOLED SIDE WALLS CAUSE PRONOUNCED CLINKER FORMATIONS WHICH SERIOUSLY AFFECT IGNITION ALONG THE SIDES

to remedy the trouble by replacing the regular fire brick with carborundum brick, but clinker will adhere to carborundum brick unless the wall is air-cooled. The decided advantage of the carborundum brick although not air cooled, is that, when the clinker is cooled, it can be broken off without tearing away some of the brick as usually happens with ordinary fire brick.

To get really satisfactory results, if a refractory material is used, there should be carborundum brick or tile, or other high-melting material but there should be air cooling. This combination really gives good results and is employed by well-known manufacturers in the cooling of stoker furnace walls.

Figure 5 shows a stoker furnace with the side and front walls protected from clinker formation by hollow, air-cooled carborundum blocks. These blocks are several times larger than standard fire brick and, besides air circulation air behind the fire-face, this air is discharged into the furnace through perforations in the blocks.

FIG. 5. CLINKER FORMATIONS ON THE SIDES AND FRONT WALLS ARE PREVENTED BY AIR-COOLED CARBORUNDUM BLOCKS

In several traveling-grate stoker installations it has been found that better results were obtained when these perforations were closed with fire-clay or some sort of high-temperature cement. The air behind the fire-face was sufficient for cooling, while that discharged into the furnace hugged the side walls and caused stratification of furnace gases. With forced-draft traveling grate stokers air often leaks along the sides more than is really needed and any further addition of air makes matters worse.

Water Cooling Is a Positive Clinker Preventative

Another excellent method of preventing clinker formation along the sides of traveling-grate stokers is by water-cooling, usually with 4-in. pipes, two on each side, placed one above the other, just above the ledge plates.

With underfeed stokers the bridge wall is sometimes air-cooled, as recommended by one manufacturer, with perforated cast-iron plates, constructed as shown in Fig. 6.

In many large furnaces, both with stoker and pulverized-fuel firing, the latest method of cooling the walls eliminates most of the refractories by the use of water tubes, having circulation under boiler pressure.

Joints Are Eliminated by Monolithic Walls

Another well-known method of solving brick work troubles, although it does not eliminate clinker formation,

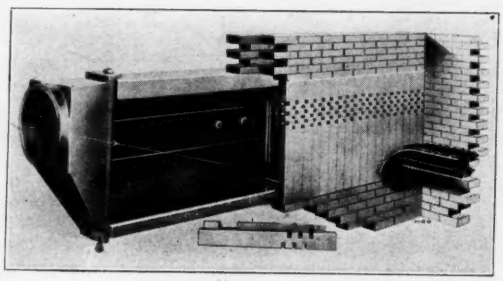


FIG. 6. AIR COOLED CAST-IRON PLATES PREVENT CLINKER ON THE BRIDGE WALL

is the construction of monolithic walls previously mentioned in reference to Fig. 9. This form of lining consists of a plastic material which is tamped into place and then vitrified with a slow fire.

With this lining, the plastic material is placed next to the insulating material and then the outside brick which is used for its strength and as a support and protection for both the insulation and the refractory. Often the outer brick is covered with an impervious paint which prevents air from seeping through the brick. As the jointless lining seals up the whole inside of the furnace, the entry of air through it is prevented. Before starting construction, pieces of channel iron are embedded in the brick work so that the plastic material can be held close to the wall by means of the protruding ribs of these pieces of channel iron.

Arch Construction and Repairs

High furnace temperatures and the greater volume of furnace gases have increased refractory maintenance and have made suspended arches almost a necessity. Sprung arches are still used in small furnaces where the temperatures are low and there is only a small volume of gas to erode the arch surface but, if the furnace is more than

10 ft. wide, some sort of suspended arch will prove a good investment.

Quite a number of excellent types of suspended arch construction are on the market, each with its particular individual method of suspending the tile. The construction of the suspended arch requires the use of cast-iron supports which are protected from the heat of the furnace by the suspended tile. These cast-iron supports must run either through the central portion of the tile, thus requiring one large groove through the center, or there must be two small grooves—one on each side of the tile.

In Fig. 7 is shown a representative type of suspended arch construction, illustrating the general principle of suspending fire clay tile or blocks from cast iron supports.

In some cases, each block or tile is suspended by an individual hook or bolt, in others all the tile in each row are slipped on a cast-iron frame which is supported at several points.

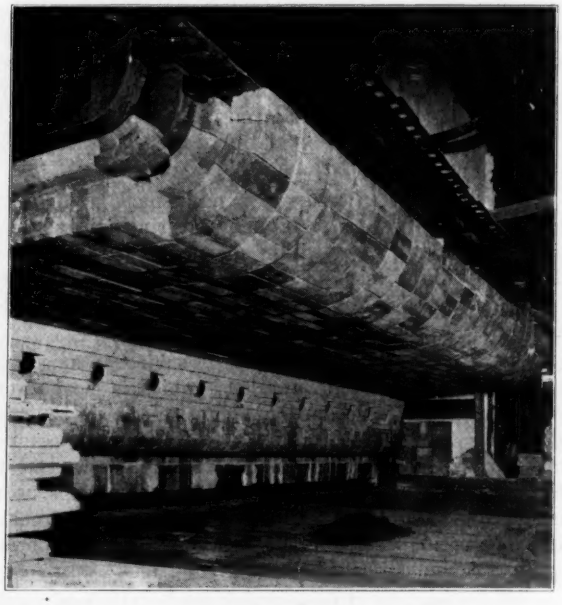


FIG. 7. TYPICAL SUSPENDED ARCH CONSTRUCTION

With the sprung arch, if any serious damage has been done, it is usually necessary to rebuild the entire arch, since each brick is dependent upon the other for support. With the suspended type of arch, even with spalling and erosion as bad as shown in Fig. 9, the more seriously damaged blocks can be taken out and new ones placed without disturbing the others.

With the replacement of a few blocks this same arch could be temporarily repaired by washing with a high-temperature cement or with the plastic material which is used for furnace linings as previously described.

Although the life of an arch is dependent on so many factors, it may be said that fairly good service has been obtained if an arch lasts for 6 mo. without repairs. On the other hand, arches of practically the same type of construction have given service for as much as 2 yr., so it is hardly possible to make any general statement of what may be expected.

Superheaters Require Inspection

Precautions to Be Observed in Operation and Upkeep

TO KEEP superheaters in good condition requires little more attention than careful inspection and needed repairs at times when the boilers of which they are a part are shut down. At this time inspection of the superheater should be as rigid as that given the boiler, particular attention being given to the observation of corrosion and points of weakness where leaks are likely to occur before the boiler is to be shut down again. Repairs should, of course, be made as soon as defects are discovered.

Corrosion may be detected by observation when the tubes have been cleaned. To detect leaks, however, the use of water under pressure while the boiler is out of service has been found convenient as the leaks show up immediately.

As the superheater is the last element of the boiler through which the steam passes, the temperature of its metal is the highest of any in the boiler unit and close attention should therefore be given to the temperature of the steam leaving the superheater, as the safe temperature limit may be exceeded in modern high pressure plants.

Causes of Overheating

Overheating of the superheater may be due to improper design and location for the conditions under which the superheater is to be operated. Assuming, however, that these features are correct, there are two causes for the superheater elements becoming overheated while in operation. The first and most common is that insufficient steam is passing through the elements to keep the temperature down, which is due to an underload on the boiler or, in some cases, to an improper setting of the safety valves on the boiler and superheater which allows saturated steam to escape before the valves on the superheater open to atmosphere. For this reason the superheated steam safety valves should be set at about 2 lb. less than the valves on the boiler.

The second cause for overheating is the accumulation of scale or steam dust within the tubes of the superheater. This accumulation may be due to flooding the superheater when starting up or to priming of the boiler. When superheaters were first used, it was the practice to flood them with water when starting up, but this has now been entirely discontinued and experience has shown that there is no necessity for protecting the superheater in this way during the firing up period.

To prevent priming of the boiler from throwing scale forming materials into the superheater, the boilers should be provided with an effective dry pipe or purifier within the boiler drum or a steam separator in the pipe between the boiler and the superheater. By observing these precautions, superheaters have operated for years without accumulating sediment inside the tubes.

Fire Slowly When Starting

When putting a boiler with a superheater in service, it is advisable to fire rather slowly, with the admission of plenty of air, in order that the flue gases reaching the superheater should not be of too high temperature. In the case of radiant type superheaters, the furnace temperature should not be too high as no steam is flowing through

the elements until the boiler is put under load conditions.

While the boiler is being fired up, the drain valve on the superheater header should be kept open so that, in case there is any water in the elements or in the header, it may be drained off and not be carried over to the main steam line. This rule applies to both convection and radiant type superheaters. No special attention need be paid to the superheater when the boiler is in operation other than blowing the soot off the tubes at regular intervals. The frequency of blowing the tubes depends largely upon the kind of fuel used, the draft and the type of superheater.

With convection type superheaters, blowing the boiler tubes in the pass ahead of the superheater causes these tubes to absorb more heat from the gas and, therefore, lowers the temperature of the superheated steam. Blowing the superheater tubes decreases the heat resistance between the gases and the steam and, therefore, increases the temperature of the steam.

In the case of radiant type superheaters, accumulation of furnace dust upon the superheater has the effect of decreasing the temperature of the superheated steam. Dusting these tubes, therefore, increases their conductivity, resulting in higher steam temperatures.

It is, of course, impossible to control the amount of superheat at will during operation, but it can be varied an appreciable amount by systematic blowing; that is, using only a part of the blowers at a time, thus maintaining the temperature as nearly uniform throughout the day as possible.

Pumps Need Constant Watching

Valves, Packings and Bearings Are Principal Problems in Pump Maintenance

TO KEEP pumps working in perfect operating condition requires careful attention on the part of the operator to all points where wear is likely to take place. This includes the valves, packing, bearings and means for lubrication. It is essential also that the operating conditions, such as suction and discharge pressure, temperature of water and pump speed are all maintained in accordance with the design of the pump.

Centrifugal pumps, which are becoming more extensively used in boiler plants, require little attention to keep them in good condition if the conditions under which they operate are suited to the design of the pump. Only two check valves are used with these pumps; one in the suction, frequently called the foot valve, and the other in the discharge pipe line located as close to the pump as convenience of arrangement will permit.

There is also a gate valve in the discharge pipe so located that when it is closed the discharge check valve can be removed from the line for repair. As the flow of water is continuous while the pump is in operation, the check valves are not subject to much wear. Even when not in the best of condition, this does not cut down the efficiency of the pump as they come into use only when the flow of water stops and when the pump is stopped, the gate valve should be closed, and this relieves the check valve of all strain. Nevertheless, these check valves should be inspected regularly as leaky valves may cause considerable loss of water if the pump stops unexpectedly. The easiest way to repair these valves is to remove them from the line and renew or re-seat the discs and seats when they have become worn or scored.

Packing Used for Pump Shaft

Packing for centrifugal pumps is of the ring type and, when used to prevent the suction from drawing in air, a water seal ring is employed. This packing may be made of fibrous material commonly known as soft packing, or it may be of metallic rings, either of the flexible, molded or spring type. This packing should touch the shaft with just sufficient contact to prevent the passage of air into the pump or the leakage of water from it, in case the pressure within the pump is greater than that of the atmosphere, such as may be the case in some designs of multi-stage pumps.

Fibrous packing is usually made up with some form of lubricant, such as graphite, in the material, so that additional lubrication is not necessary, particularly when a water seal is used, as the water itself acts as a lubricant. In the case of metallic packing, however, all types are not provided with self-lubricating features, so that it is frequently necessary to provide lubrication for these packings.

Leakage between stages of multi-stage centrifugal pumps is usually taken care of by labyrinth rings which depend upon the water within the pump for lubrication. These should be inspected regularly and renewed when wear is evident, as leakage here results in slip or lowered volumetric efficiency.

Centrifugal pumps are frequently subject to axial motion caused by hydraulic unbalance which is most severe in single stage single suction pumps and may be quite noticeable in multi-stage pumps if the design does not make provision for eliminating this end thrust. Due to the small clearance in the labyrinth packing rings, wear is likely to occur here which will give frequent trouble, if axial motion is not eliminated, thrust bearings being quite commonly used for this purpose.

All the bearings of these pumps need continuous watching to insure that they are getting proper lubrication and not becoming unduly hot. Bearings should also be inspected regularly to make certain that the wear is not destroying the alinement of the pump shaft with the bearings of the motor or turbine to which the pump is attached.

Worn bearings place a strain upon the packing and labyrinth rings and throw the impeller off center with respect to the pump casing, thus resulting in lowered efficiency, leakage past the shaft packing and undue wear of the labyrinth rings. Inspection should also include observation of the impeller for erosion and clogged passages.

Lubrication of the centrifugal pumps is limited to the shaft bearings and, in certain cases, to the metallic packing glands and thrust bearings. Bearings in centrifugal pumps are usually of the ring oiling type. The care of the bearings, therefore, consists in keeping plenty of cool, clean oil in the wells. The oil should, of course, be of the proper quality for the bearing which it supplies and should be renewed at regular intervals.

Inasmuch as the upkeep of centrifugal pumps is largely a matter of proper operation, the following rules are of value in the handling of boiler feed pumps. When starting the pump, the first operation should be to open the valve on the pressure gage line on the discharge side of the pump. Then open both the suction and discharge valves if these are provided in the installation. With a steam-driven unit the next step is to open the drains and exhaust valves and warm up the turbine. The valves to the pressure regulator should be closed. If the bearings on the unit are of the water cooled type, this cooling water should be turned on to the bearings and also the seals. Next, inspect the entire unit's oiling system, seeing that the supply of lubricant is ample, and if the system is of the gravity or pressure feed type, see that the oil is fed properly to all the bearings.

After this preliminary work has been done, the turbine or motor should be started slowly and gradually brought up to working speed and pressure. At this point observe whether or not the proper pressure is on the equalizing pipes to balance the thrust. Then open the steam and water line valves to the pressure regulator and adjust the regulator to give the proper differential between the feed pressure and the steam pressure. When pumps that are not equipped with a load equalizing device are run in parallel, the load may be equalized by slowing down the speed of the pumps which are taking the most load. If the pump becomes steam bound, open the spray line valve which will admit cold water and condense the steam.

When a turbine- or motor-driven pump is to be shut down, turn off the steam or pull the switch and see that the pump comes to rest, close the spray line valve if it is open, shut off the oiling system if of the pressure or gravity feed type, close the turbine exhaust valve, close the suction and discharge valves, shut off cooling water from bearings and seals, close the steam line to the pressure regulator and adjust the water line valve to the pressure regulator according to regular practice.

Problems in Operating Reciprocating Pumps

Reciprocating pumps present operating problems entirely different from those met with centrifugal pumps. The valves in this case are in decks and, while their action is similar to that of a check valve, they must operate quickly, both in opening and closing, giving as little resistance to the water as is possible, but must close quickly when the pump piston reaches the end of its stroke.

This action is rather severe on the valves and, due to their service, they are likely to become scored and cause leaking or to stick open, thus impairing the efficiency of the pump. Leaks may be due to warping or erosion. Sticking may be due to weak or broken springs, worn valve stems or foreign matter under the valve disc. Leaks are not easy to detect, usually requiring the opening of the pump, although, occasionally, leaks may be detected by jerky action of the piston.

Leaking suction valves may be noted by closing the gate valve in the discharge pipe and, under this condition, if the piston can be operated in either direction with the cylinder heads in place and the discharge valves in good condition, it is evident that the suction valves are leaking.

Leaking valves, whether due to scoring or warping, may be repaired by grinding the valve seats and discs, or renewing the valve discs. The valve springs need regular attention as the work which they perform is severe and a failure of the valve means practically a failure of the pump to operate.

Valve springs are subject to corrosion, ends become worn, they may lose their elasticity and become crystallized, get out of place and out of pressure adjustment. For any of these defects, except the last, replacement of the spring is the best remedy.

Attention to Pump Packing

Packing reciprocating pumps is in many cases the most troublesome problem with which the pump operator has to contend. The purpose of packing is to prevent leakage past the piston, plunger or rod. The difficulty is to accomplish this purpose without undue friction and so to adjust the pressure that the packing does not wear out rapidly. Either fibrous or metallic packing may be used.

Where fibrous packing is used in the pump, boxes should be filled full and the glands tightened down only moderately. After the pump has been in operation, the rod packing can be tightened until leaks are stopped by tightening the glands. In case excessive tightening is required to stop leakage, the packing should be completely renewed.

Pistons and plungers used in cold water pumps and packed with fibrous packing usually take four rings ¾ in. square. These packing rings should be cut about ⅛ in. short of meeting in order to give room for expansion and should be fitted into the recess with moderate tightness and placed so as to have the joints out of line with each other. Packing of this type may be lubricated with cylinder oil and graphite which not only reduces the friction on the pump during operation but makes the rings easy to remove.

Pumps of the plunger and ring type require no packing, the plunger being made a close fit with a metal ring held in the center of the cylinder by studs. Clearance of about 0.001 in. is allowed and the ring is made of bronze so that any scoring will take place on the ring and not on the cast-iron plunger.

In recent years the use of metallic packing for pumps has become more common and, as the different forms of this packing work on somewhat different principles, this packing should be used according to the instructions given by the manufacturer.

Bearings of reciprocating pumps require the same care as those on centrifugal pumps. In direct-acting pumps, the bearings are small and frequently of the brass lined type. These should, of course, be properly lubricated, the method ordinarily employed being sight feed oil cups or, in some cases, grease cups are used. Lubrication should not be neglected, as it is an easy matter to overlook small bearings and excessive wear results.

Forced feed oil pumps delivering the oil directly to the surface of the cylinder make the best means for delivering cylinder oil to the steam end of the pump. A hydrostatic lubricator, however, may be used for this purpose. The oil used for lubricating the cylinder should be selected to suit the individual needs of the pumps, frequently a compounded oil gives best service, as the exhaust steam is generally used for heating feed water and oil can be so compounded that it will separate out of the condensate and can be removed by an oil separator and filter in the heater.

Operation of Ash Handling Machinery

Discussion of Care of Various Types of Equipment in Use and Method of Testing for Combustible in Ash

AT THE present time, systems used to remove ash from power plants are usually of the mechanical conveyor, steam or vacuum conveyor, hydraulic system and the gravity system types. In the last case, little need be said of operation, since in a plant where this system is used, it is necessary to have the plant designed so that industrial or railroad cars are run under the ash hoppers of the boilers and the ash is dumped directly into them.

In case ash is dumped direct into industrial cars, they may be run on tracks to one end of the boiler room basement and dumped into a skip hoist, which hoists them to a storage tank. Such skip hoists are usually operated by an electric motor hoist. The operator, after pressing a button to start the loaded skip, returns for another load of ash. Meanwhile, the motor hoists the skip to the storage tank, a solenoid brake stops it and holds it in position

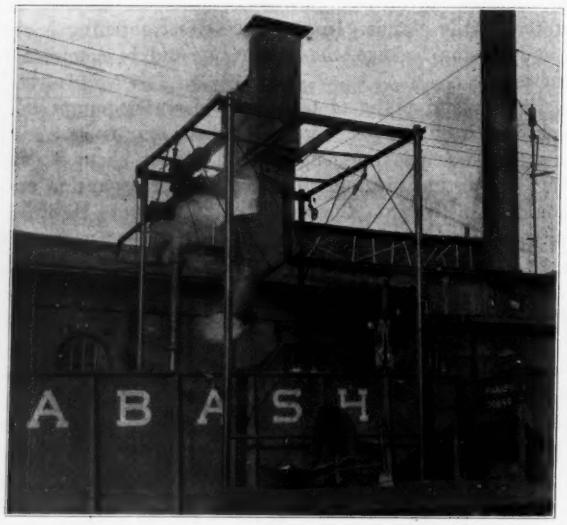


FIG. 1. STEAM JET ASH CONVEYOR DISCHARGING DIRECT INTO OPEN CAR, SHOWING ABSENCE OF DUST CLOUDS

until it has dumped and the skip is then lowered automatically for another load. Such an ash-handling system requires the same attention to lubrication of the driving motor and inspection of cables, skips and electrical devices that are given to any boiler plant equipment. Rollers of skip and counterweight must be well oiled and the hoisting motor or engine and the control board should be kept dry.

Various types of chain, bucket and drag conveyors are often used for ash handling. It is considered better to handle ash with a conveyor separate from the coal-conveying system, to avoid the tying up of a combined coal and ash system when handling one or the other. When bucket conveyors are used for handling ash, with the buckets mounted on chain, the runways should be kept well greased to eliminate wear. On the other hand, if buckets are mounted on roller chains, no grease or oil should be used on the runways. For such chains, provision is often made in the design for oiling joints, some installations being equipped with high-pressure fittings for roller lubrication. Bolts in buckets and bearings should be kept tight and all gearing and bearings well lubricated. To the various types of scraper and drag chain conveyors used for ash handling, the above remarks also apply.

Care in installing and replacing chains on the above conveyors will eliminate much trouble. The closed or hook end of chain should be run first. Chains should not be operated faster than the maximum speed rating.

Steam Jet Conveyor Operation Influenced by Design

Operation of steam jet conveyors, correctly designed to cover conditions peculiar to plants in which installed, as with any other equipment in a power plant, require some attention from an individual. This on the presumption that the manufacturer has made provision in design for all factors entering into the problem of ash disposal. These factors are: steam consumption, capacity, maintenance or repairs, and delivery of ash at the conveyor terminal so as to eliminate damaging, costly, and dusty discharges, coincidentally leaving the ash in a condition that makes rehandling convenient and inexpensive.

The maximum rate at which the conveyor will handle ash depends on the characteristics of the ash itself and on the design of the conveyor and, to a large extent, is beyond the control of the operator. It is advisable to design ash pits to obtain a gravity flow to the conveyor, thus enabling the operator, with the least physical exertion, to feed at the maximum rate. Feeding of a steam jet ash conveyor need not be intermittent, but can be continuous, providing the equipment is properly designed. The operator's function in maintaining the repair cost at the lowest possible point is to inspect the system every 30 or 60 days to make certain that replacement of parts specially designed to take the wear is made before that wear extends beyond its normal scope.

Dusty emanations from the conveyor must be prevented. If the conveyor discharges into an open pile or car, a slight amount of water may be injected into them to prevent dust. The use of excessive quantities of water is to be avoided, however, because it makes a mess and in winter results in freezing. With a properly designed terminal auxiliary on the conveyor, it should be possible to deliver the ash, free from damaging dust clouds, in a loose condition, making possible its rehandling with ease with an application of water not exceeding 10 per cent of its own weight, which amount does not become visible or apparent in the delivered ash. This function should be automatic and integral with the conveyor.

Ash packs tightly when moist; the ash should be delivered in the bin dry and if the terminal equipment is correctly designed, the ash is precipitated into the bin with practically a gravity drop, rather than with a forcible impact, which would cause packing. It is necessary to make provision for the exhausting of the air and steam from the tank to prevent the accumulation of back pressure. A plain vent to the atmosphere would permit the escape of the steam and air, but with an accompaniment of dust clouds. It is necessary, therefore, to eliminate this dust with a correctly designed dust eliminator, which will extract the dust from the steam and air, permitting its escape to the atmosphere without any visible discoloration.

This function also should be automatic and entirely beyond control of the operator.

From the foregoing it will be noted that the entire work of the operator consists in: first, properly draining condensate from the steam supply line to the conveyor; second, turning on the steam to the conveyor; third, feeding the conveyor with ash; fourth, after complete disposal of the ash has been effected, shutting off the steam supply. All other functions can be made automatic.

Operation of the vacuum type of ash conveyor is somewhat similar to the above, although the principle of it is different. In this device, a vacuum is created in a tank either by a power-driven exhauster or by a steam jet exhausting to the atmosphere. A pipe with loading ports is used to convey the ash and the inrush of air through this pipe carries the ash along to the tank.

Ash Is Often Removed by Hydraulic Methods

Sluicing and pumping of ash are now being used to a considerable extent. In one method, ash drops from the furnace to a hopper where it is quenched by sprays and washed into a sluiceway as shown in Fig. 2, where intermittent discharges of water at high pressure carry it along out of the plant. In other types, a continuous water stream is used. Sometimes the ash is sluiced to a sump, where it is picked up by specially-built ash pump and pumped to some distance to be used for filling.

In handling ash with water, one important consideration is the danger of dropping masses of ash suddenly into water, particularly where large clinkers are found. The tremendous heat generated might cause a steam explosion. Furthermore, dry ash should not be allowed to drop through the air in a boiler room basement, without making some provision for removing the gases and dust that result.

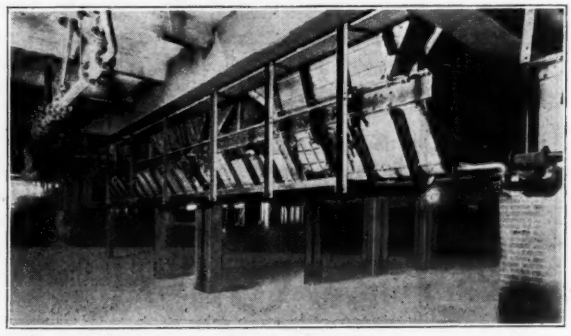


FIG. 2. HIGH PRESSURE WATER JETS WASH ASH THROUGH SLUICEWAY TO SUMP, WHERE ASH PUMP PICKS IT UP

Ash hoppers and gates are usually counterweighted and arranged so that the operator, standing well clear of them, can open and close them with a long handle. They are sometimes power operated with steam, air, or oil pressure.

Removal of ash from pulverized fuel furnaces presents many problems, since the temperature of the ash when it gets down to the bottom of the furnace must be below the fusing point if slagging and clinkering are to be prevented. Water screens are often used, the ash dropping through them into hoppers, from which it is removed by various methods noted above. In addition to this ash, it is estimated in pulverized fuel operation that from 12 to 25 per cent of the ash in the coal will pass out through the stack in flocculent form unless it is entrapped.

Several methods are used to entrap this ash at the stack. In some cases an induced draft fan is designed to catch cinders and ash; one design of such fans is shown in Fig. 3. In another type, baffles are arranged in the scroll case of the fan, the fan rotor being of standard design. Another type of ash-catcher employs a centrifugal separator connected with the stack, the gas being forced into it by the induced draft fan. An electrical method of catching fine ash in the stack, employing the Cottrell pre-

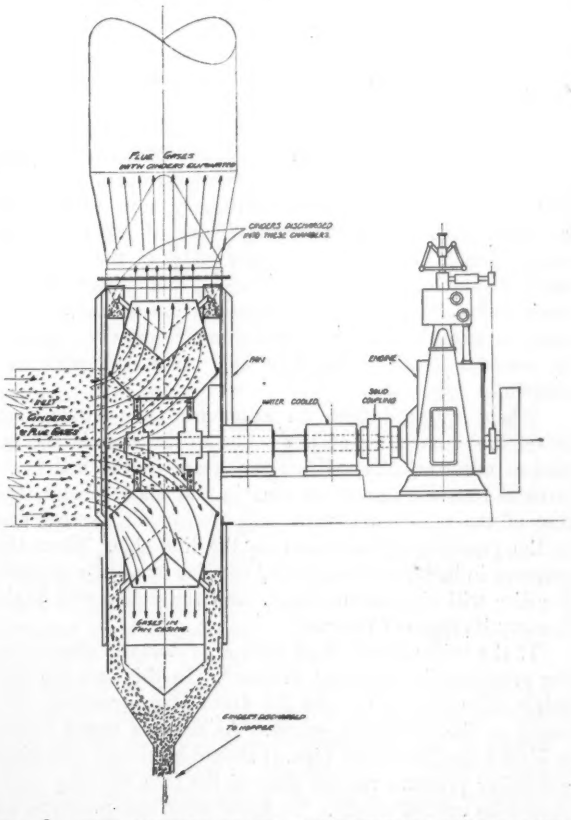


FIG. 3. THIS INDUCED DRAFT FAN PREVENTS FINE PULVERIZED FUEL ASH FROM PASSING OUT THE STACK

cipitator, is in successful use at the Trenton Channel plant. In this device the flue gas is passed between oppositely charged electrodes that produce a strong electrostatic field and the ash is precipitated by the action of this field.

To determine the amount of combustible carried out of the furnace with the refuse, an analysis should be made similar to that which determines the ash in coal. The refuse is dried at about 10 to 15 deg. C. above room temperature or, on an average, at about 100 deg. F. If the ash has been quenched, the analysis should take account of this fact and should reduce the final result to the same basis as the coal analysis. After drying, the ash sample is weighed carefully and then placed in porcelain crucibles and heated slowly to redness to avoid too rapid expulsion of volatile matter. After heating slowly for a time, the sample is heated at about 1300 or 1400 deg. F. to constant weight. The final weight subtracted from the initial gives the amount of combustible, on an air-dried basis. A gas or electric muffle furnace is necessary for this test. The accuracy of weighing and the like will depend on how closely the heat balance is being computed.

Steam Control and Measurement

PRECAUTIONS TO OBSERVE IN CUTTING BOILERS IN AND OUT.
MEASUREMENT OF STEAM BY THE USE OF STEAM FLOW METERS

WHEN CUTTING A boiler in on the line several precautions must be observed to avoid any sudden strain on the connected piping due to changes in temperatures, pressure or both. Chief among these several precautions is the necessity for equalizing the pressures on both sides of the stop valve before opening it. If the pressure of the unit to be cut in is either higher or lower than that in the steam main, the opening of the valve, especially if it is done suddenly, will impose a severe shock upon both the boiler and the piping.

The manner in which the boiler is placed on the line depends largely upon the arrangement of valves in the steam connections. In Fig. 1 are shown two arrangements, one with both automatic and ordinary stop valves and the other with just a single stop valve of the non-automatic variety. If there is only one boiler in the plant the latter arrangement may be sufficient, but where two or more boilers having manhole openings are connected to a common steam main, two stop valves are usually required by law and it is customary in such cases to provide one automatic valve.

When equipped with an automatic, non-return stop valve, the connecting of the boiler to the line is accomplished automatically. Until the steam in the boiler attains the same pressure as that in the main header, the disc of the non-return valve will remain on its seat due to the pressure of the steam on the line side. When the pressure in boiler reaches that of the line or a little greater, the disc will rise automatically and the boiler will begin to carry its share of the load.

If the boiler is not fitted with an automatic stop valve, the procedure is somewhat different. In this case the first thing to be done is to open the drain pipe permitting any water in the header to escape. As soon as steam begins to blow out of the drain pipe, it should be closed, and when the boiler pressure reaches that of the line, the stop valve should be opened slowly. To know when the pressures on

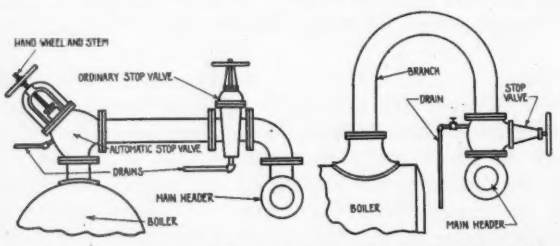


FIG. 1. ARRANGEMENT OF VALVES IN BOILER HEADERS

the two sides of the stop valves are equal it is extremely important to have accurately calibrated steam gages.

In large central stations the procedure of putting a boiler on the line, although the same in principle, is more complicated, because of the more eleborate layout of the station. It is becoming general practice in these large stations to operate all the high pressure valves electrically from control boards placed in the firing aisle.

Electrically controlled valves were first used for purely emergency purposes, that is, to afford a means of closing the valves in case of a ruptured steam line or similar accident which would prevent anybody from gaining access to the valves. At the present time, however, they are used in the daily operation of the plant and have found considerable favor, generally. Control stations are placed at various points, one usually being located at or near the valve, one on the boiler control panel and another on the emergency board near one of the exits to the station. In the operation of these valves the same precautions must be observed that are observed in the operation of hand operated valves as regards the relative pressures on the boiler and line sides of the stop valves.

During the period of warming up a boiler, the steam pipe drains and the safety valves are usually opened to allow escape of air and condensed vapor. If the entire plant is to be started up, the stop valves are also left open at times but most engineers prefer to keep the stop valves closed until the steam is formed, discharging the air through the safety valve or in some cases through a specially provided vent. Where the stop valves are kept closed, bypasses should be provided around the valves so that the line on the engine side of the stop valve may be warmed up gradually.

FLOW METERS

Steam flow meters for use in boiler rooms are available in a number of different types and can be secured either for indicating or recording the flow at the point where it is measured or for indicating or recording it at a point some distance away from the steam line. The steam flow meter has undergone great development during late years and today the average high-grade meter is both accurate and reliable, provided the quantity of steam measured is within the limits specified by the manufacturer, and

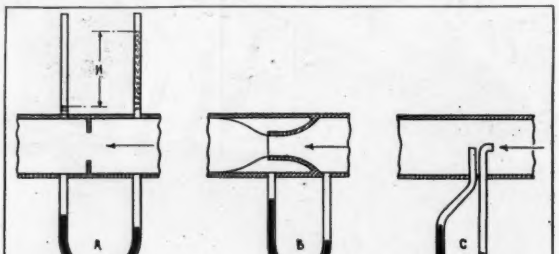


FIG. 2. DIAGRAMS SHOWING METHODS OF CREATING PRESSURE DIFFERENTIAL. (A) ORIFICE. (B) NOZZLE. (C) PITOT TUBE

also that the rate of flow pressure and quality is maintained constant. For low capacity, interrupted or intermittent flow and for sudden variations in pressure or quality the results are not so reliable and should not be relied upon too closely.

Most meters for measuring the flow of steam in pipes measure in reality a difference in pressure created by a change in the velocity of the steam. In order to create the difference in velocity, some constricting device is placed in the pipe as illustrated in Fig. 2. In passing through an orifice, (a) or a flow nozzle, (b) the velocity of the stream is increased, while the pressure is reduced as compared with conditions in the pipe upstream from

the device. In the Pitot tube, (c) a difference of pressure is created by stopping the velocity entirely in the impact opening of the Pitot tube, that is, there is an increase in the pressure of the fluid instead of a decrease.

A complete flow meter includes, essentially, first, the device which creates the difference in pressure as explained, and second, an apparatus which utilizes the difference in pressure to indicate, record or integrate the flow in the pipe. The first is known as the metering element and the second the recorder.

in the primary. This causes a proportional increase in the primary current which is indicated by an ammeter calibrated in terms of steam flow. The principle of this meter is shown in Fig. 4.

A more direct use of the pressure differential than that employed in either of the methods described is shown in the meter in Fig. 5. Here there is a difference in pressure between the inside and outside of a bell floating in mercury. When the pressure inside the bell increases, the bell is pushed upward, and, as it rises from the mercury the

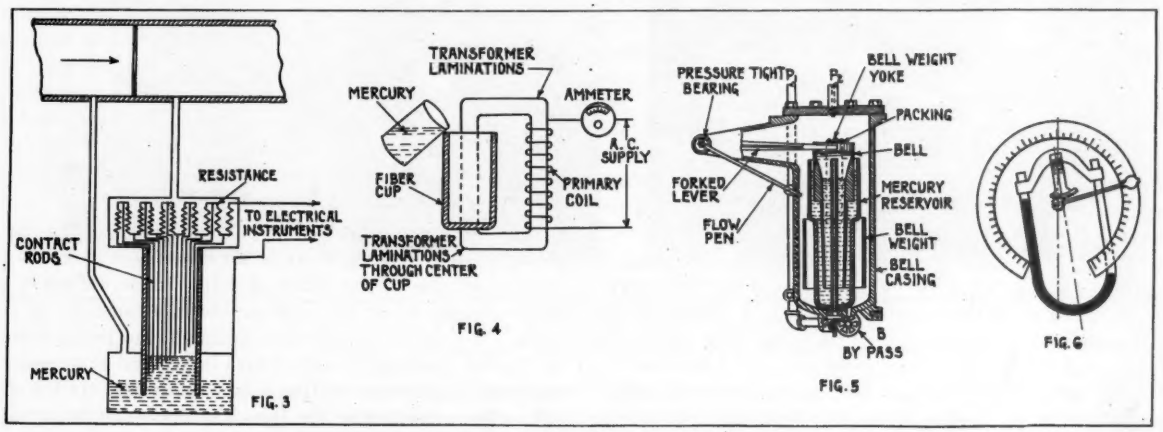


FIG. 3-6. PRINCIPLES EMPLOYED IN A NUMBER OF COMMERCIAL FLOW METERS

Most of the flow meters in use today, use either an orifice or a nozzle in the steam line to produce the pressure differential necessary to actuate the recorder although there are several makes which use an entirely different principle. One meter in particular utilizes the effect of the centrifugal force of the steam as it passes through a specially shaped elbow having a rectangular hyperbolic section. Another meter makes use of the orifice and plug principle. This meter differs from the ordinary flow meter in that it records the weight of steam passing through the seat of an automatic lifting value which rises and falls as the demand for steam increases or diminishes.

It is in the recorder or indicator element that the great difference between flow meters exists, that is, in the method of utilizing the pressure differential. Several of the principles used in modern meters are illustrated in the accompanying illustrations.

In Fig. 1 is shown a diagram of a meter in which the pressure differential produced by an orifice in the steam line causes the height of a column of mercury to rise and fall in proportion to the flow of steam in the pipe. The rise and fall of the mercury makes contact with the successive ends of vertical rods, thus cutting out the resistances to which the rods are connected and thereby regulating the amount of current flowing through the electric circuit. The resistances are so divided by the contact rods that the flow of current in the circuit is directly proportional to the flow of steam in the pipe. This flow is indicated or recorded directly by the reading instruments.

In another type of electrically operated flow meter a similar method is used insofar as the rise and fall of mercury level is concerned, but instead of cutting in and out resistances, the mercury forms a closed ring around the primary element of a transformer. This ring acts as the secondary circuit of the transformer and as it rises more and more current is induced in it by the current flowing

change in the buoyant action of the mercury on the walls of the bell balances the force due to the pressure difference. This motion of the bell is transmitted direct to an indicating hand traveling over a scale, graduated in terms of steam flow. The shape of the bell and thickness of wall and weight are designed so that the lift is directly proportional to the rate of flow through the orifice.

In Fig. 6 we have still another method of utilizing the pressure differential as used in a commercial flow meter. Owing to the different pressure in the two sides of the U tubes, the level of the mercury in the two legs assumes different levels causing the pivoted frame to rotate until its center of gravity is directly beneath the point of support. This movement is transmitted by gears to a moving pointer.

It must be apparent from the description of the principles governing the action of various types of flow meters just given that no general rules can be laid down for the care and maintenance of all flow meters. Each make requires the attention peculiar to its construction and unless given that attention must not be expected to give accurate indications. The chain of events from the actual creation of a pressure differential and the indication of this pressure difference in terms of flow is often a complex one, beset with many chances for the creeping in of errors.

In the electric type of flow meter, it is extremely important that the voltage of the supply mains be maintained constant, since any variation in voltage would cause erroneous indications. The quantity of mercury in most of the meters using it must not be varied, and if for any reason any of it is lost in making adjustments the instrument must be recalibrated.

Since the pressure difference set up by an orifice, nozzle or other arrangement is of a comparatively small value, the lines must be kept absolutely tight at all times.

Upkeep and Maintenance of Stacks

PROPER UPKEEP and maintenance of stacks is important for two reasons: first, because with a leaky stack the efficiency of the boiler units is impaired; and, second, because a stack in poor repair is in danger of coming down and is, therefore, a source of danger to life and property.

All stacks should receive careful systematic inspection both inside and out. Steel stacks must be kept free from corrosion, the seams and rivets must be tested for tightness and strength; the exterior should be painted at suitable intervals; the foundations should be examined for settling, cracks and disintegration; the wind braces and guys taken up when needed and kept free from rust. The breeching, whether steel, brick or concrete, must be kept tight since a leak in this part of the system is highly detrimental to efficient operation of the boilers.

Methods of conducting inspection vary according to local conditions. If there is a permanently installed ladder on the exterior of the stack it is usually a simple matter to install a sling which may be let down from the top so as to permit a man to inspect every portion of the exterior. A good telescope or a pair of high powered binoculars sometimes proves useful in locating areas of the exterior surface which need attention.

Brick stacks, if properly constructed, require little attention, but should be tested occasionally to see whether the draft produced is at the required value. If it is found to be low, the stack should be examined for leakage and the defective spots pointed with a good grade of mortar.

In painting stacks certain fundamentals must be followed if a satisfactory paint job is to be obtained. Steel stacks should not be painted when wet, nor during damp or freezing weather. The temperature of the stack should in no case be over 300 deg. F. at the time the paint is applied; a temperature of 200 deg. F. would be considered just right.

Paint applied over dirt, rust and loose paint will not give satisfaction. Therefore, scrapers and wire brushes should be used to obtain a good clean surface to which the new paint may be applied. The galvanized surfaces should either be etched with a 20 per cent acetic acid solution or allowed to weather for from 6 to 9 mo., after which the first coat of oil paint mixed with 15 per cent naptha may be applied.

It is essential that the paint be evenly applied and thoroughly rubbed out to exclude all air from beneath its surface. A round stiff brush is probably best for this purpose. During cold weather, tar and asphalt paints may be heated up to 150 deg. F. to facilitate application Stack paints should not be thinned with gasoline or benzine. In extreme cases, a small percentage of turpentine may be used for the purpose of thinning. Paints used for high heat resistance are mixed with a special oil; therefore, when ordering, a statement should be made as to the maximum temperature to which the surface should be heated. Coal-tar paints may be used for surfaces where the temperature does not exceed 450 deg. F. Once used, however, it is necessary to clean off the old coat before repainting. Graphite paint will withstand high temperatures and it is comparatively easy to apply.

Brickwork in the interior of steel and masonry stacks is subject to erosion and disintegration similar to that which takes place in the interior of furnaces, although, because the temperatures in this case are much lower, the damage is considerably less than in furnaces. In furnaces the refractories often melt; in stacks, the trouble is usually due to shrinkage of the mortar between the bricks and unequal expansion of the brickwork. To keep the stacks tight and to guard against serious damage to the stack linings, they should be inspected whenever conditions permit and the defective areas repaired. If the damaged portions cannot be effectively repaired by filling the joints with a plastic refractory, they should be torn out and new bricks put in.

At the present time a number of plastic refractories, used extensively in furnaces which can also be used to surface the interior of stacks, are available. These are easily applied and, since such a lining is free from joints, possibility of leakage is lessened considerably.

In steel stacks not lined or in that portion of the stack above the brick lining, there is always danger of corrosion of the steel due to the action of sulphuric acid formed by the condensation of flue gas on the cool surfaces of the stack. If evidence of corrosion is found, the plates should be cleaned thoroughly with a wire brush and then treated with some high heat resisting paint or coating. If the corrosion has proceeded so far that it almost extends through to the outside of the stack, the damaged portion should be covered with a patch in the same way that a patch is placed on a boiler.

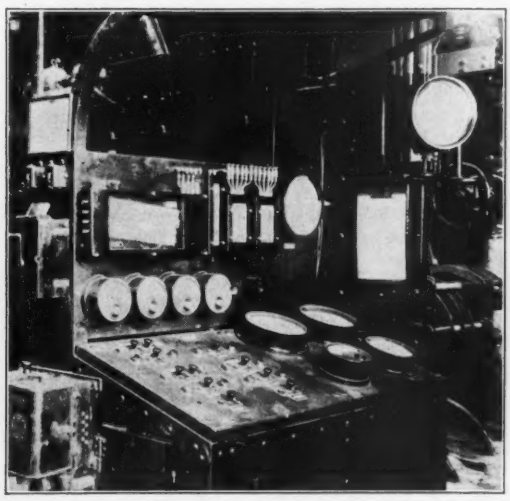
Repair of Steel Stacks With Cement

A novel as well as highly satisfactory method of repairing old steel stacks, or any other type of stack for that matter, is by concrete applied with what is known as a cement gun. With this method, which is being used widely at present, the old stack is entirely surrounded with a coating of concrete.

In repairing stacks in this fashion, vertical reinforcing rods are first installed around the outside of the old stack tied together with a horizontal reinforcement consisting of wire mesh supplemented with rods. The cement which usually is a mixture of No. 2 Torpedo sand and Portland cement, is shot into place with cement guns at a pressure of from 35 to 60 lb. per sq. in. The advantage of this method is that it is thoroughly effective and it can be done while the stack is hot. It is simple, rapid and no particular precautions need be observed except that when the stack is hot, the cement should be kept thoroughly sprinkled until it has set. What is actually accomplished is that a new stack is erected around the old one and, if the job is done correctly, it will not matter if a portion of the original stack corrodes from within for the new cement stack is not in the slightest degree dependent upon the steel shell for its support.

In certain cases, where this means of salvaging a worn out stack has been used, it has been found of advantage to place a layer of asbestos board between the steel stack and the cement, that is, the asbestos board was placed around the stack before the cement was applied. This acts as a compressible sheathing so that contraction and expansion stresses due to the varying temperature of the stack will not be communicated immediately to the concrete which naturally responds more slowly to temperature changes than steel.

Boiler Room Tests



Weighing Coal and Water and Observing Combustion Conditions Are Essential for Best Results

IT IS really surprising how few engineers in industrial plants know the efficiency of their boiler rooms. They scarcely know even what load the boilers are carrying. They haven't the slightest idea of the percentage of CO_2 in the flue gas or the temperature and the coal consumption is gaged usually by the car weights per week or month.

Central station operators are generally alert—they cannot afford to guess—they must know. The operation of the boiler room and the generation of power reduces their income directly. But with industrial owners and operators, the boiler room is merely an auxiliary plant for some process. The money is made from this process and not directly from the boiler room; therefore, the boiler room is shunted to the background.

In the average industrial plant possibilities for saving in the boiler room are greater than in any other place in the plant, provided that proper observations are made and records kept.

Power Plant Should Be Run on Business Basis

A power plant should be run like any other business. To carry out the conditions of a business, call the chief engineer, the manager of his department, and allow him to sell his commodity to the other departments in the plant.

First establish a minimum profit which he must make and then, by budgeting, allot him a certain amount of money per year to run his department. Of course, until some sort of standard has been established, various estimates may have to be changed several times. On the basis of past costs, meager though the information may be, it may be found, perhaps, that 30 cents per 1000 lb. of steam is a fair figure to charge those departments which use steam, and, say, 2 cents per kw-hr. for electricity.

These figures are given only for illustration. A basis of reckoning cannot be arbitrarily decided and, in most cases, it will be found necessary to conduct several evaporation tests in order to establish "bogies" for fuel consumption, steam cost and power cost. After this, daily routine tests or recording apparatus will tell the engineer whether he is gaining or losing.

If the engineer can produce steam and electricity for less, he is to be credited with a saving and he and his crew given a bonus on the basis of their saving. It is to be understood, of course, that he is to be given such instruments and equipment as are necessary to gage his operation and the progress made in his saving campaign.

Chief Should Be Authorized to Buy Equipment

If a chief engineer is really deserving of the title, he will be a good judge of coal and should have some voice in its selection. He should be the final authority on the quality of coal purchased instead of, as is so often the case, a purchasing agent who generally knows nothing about coal or the manner in which it is used. The latter is the autocrat of the power plant, who buys in the cheapest markets regardless of quality, so that he may show low expenditures for the year. The engineer is the one who bears the brunt of such a policy.

But even the engineer's judgment may err at times unless some sort of specifications have been adopted.

Purchasing coal on a B.t.u. basis is not recommended except in special instances. Getting the greatest amount of heat units for a dollar would be all right if, at the same time, coal with characteristics suitable to the furnace in which it is to be burned could be purchased. Certain coals such as New River, Georges Creek, or Pocahontas, have a high calorific value, but they have only a small amount of volatile matter and are slow-burning. They are not adapted to natural draft stokers where there are sudden changes in load. Unless there is nearly a balanced draft in the furnace, coals with a low volatile content will not effect a quick pickup.

On the other hand, if the plant is small, the boiler settings are low, and the firing is done by hand, it will be found advantageous, in many cases, to purchase the eastern coals mentioned above. Coals with high volatile matter as found in mid-western mines require a comparatively large combustion space to prevent excessive smoke. Also, they generally have a high ash content with a fusion point much lower than the ash in eastern coals.

When hand-firing, the fusion temperature of the ash is an important consideration. If the ash has a low fusion temperature, the fuel bed should not be disturbed. This is

not possible with hand-firing or underfeed stokers, so that traveling-grate stokers are best adapted to this fuel.

A few of the items to be considered in selecting coal are:

1. Adaptability of coal characteristics to furnace design and firing equipment; 2. fusion temperature of the ash; 3. sulphur content; 4. proper sizing.

Coal Consumption of Each Unit Important

After selecting the proper fuel, some means should be provided for weighing or measuring it. This is not as

FIG. 1. IN PLANTS WHERE THE COAL IS NOT WEIGHED, A METER OF THIS TYPE MEASURES THE VOLUME OF COAL

easily done with hand firing as with other methods, although there appears to be no reason why it cannot be arranged. If there is a platform scale available, it should be provided with a special platform, made to fit on over the regular one. Then, there should be two runways for pushing a wheelbarrow on and off as shown in Fig. 1.

This same arrangement may be used either in daily operation or when running a test. Care should be taken to have neither runway touch the platform. Set the empty wheelbarrow on the scales, run the movable weight or poise out until it exactly balances the weight of the barrow and lock it in position with the thumbscrew.

Next, put weights on the scale pan to correspond to a net weight of 250 or 300 lb. of coal. Fill the barrow with coal, run it on the scales, and add or take off coal until the scales balance. This is easily done by having a small pile of coal beside the scales. If the weights on the scale pan represent, say 300 lb., the net weight of the coal in the barrow is exactly 300 lb. This coal is wheeled in front of the boiler and dumped on the clean floor and the barrow is returned for another load.

Each time the barrow of coal is weighed on the scales and removed, a tally mark should be made on a board nailed to the wall beside the scales. Each tally mark represents 300 lb. of coal, since the amount of coal in the barrow is adjusted at each weighing, so that the scales just balance. At the end of each hour, therefore, the number of tally marks is multiplied by 300, and the product is the weight of coal used, provided it has all been fired; but, if any coal remains in front of the boiler at the end of each shift, it must be gathered up and weighed and its weight must be subtracted from the total weight indicated by the tally marks to get the number of pounds of coal actually fired.

If a regular evaporation test is run, it should be started with no coal in front of the boiler and the condition of the furnace should be the same at the end of the test period as at the start. Therefore, at the moment the test is begun, observe the thickness of the fuel bed and the condition of the fire. If the fire was cleaned, say an hour before the test began, see that it is cleaned an hour before the time when the test is scheduled to end. If the coal was fired, say 8 min. before the test started, the last coal used during the test should be fired 8 min. before the end of the test. The object of these precautions is to insure the same conditions at start and finish, as nearly as possible; otherwise, the coal weighed will not be the same as the coal consumed.

Care must be taken to make a tally mark each time a barrow of coal is run off the scales. By setting the scales so as to show any net weight, such as 250 or 300 lb., and making each barrow load exactly this weight, much time is saved, as it is unnecessary to change any of the weights or the position of the rider on the scale beam.

When sampling the coal, take from 4 to 6 lb. from each barrow and throw it into an air-tight can near the scales. Do this before the coal is weighed. These small amounts from the various barrow loads will then give a fair average sample of the coal used.

If no scales are available, there may be a coal car such as is used for hand firing in many plants. This car is provided with a hinged side to permit coal being shoveled out easily. When this side is up, the volumetric capacity of the car can be computed quite readily. If, for instance, the car is 3 ft. long, 2 ft. wide and 18 in. deep, then the capacity is 9 cu. ft. Next, we find the weight of a cubic foot of the coal, multiply this weight by 9 and the result will be the weight of one car of coal.

The density or weight per unit volume of different coal varies but, generally speaking, a cubic foot of bituminous coal weighs about 50 lb.

To get the exact weight, it is a simple matter to carry a representative sample to a small scale. As a container

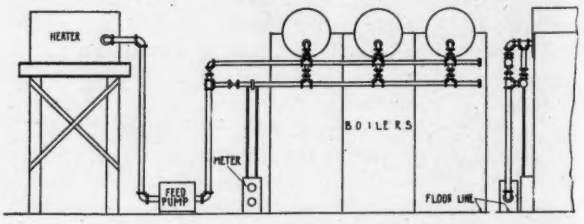


FIG. 2. ARRANGEMENT OF FEED WATER PIPING FOR MEASURING WATER TO ANY ONE OR ALL BOILERS

for the sample, any box or bucket of known capacity will suffice. Suppose that an ordinary 14-qt. water bucket is available and after filling this level full, the net weight is found to be 27 lb. This would mean that the coal weighs 48 lb. per cu. ft. and the car of coal weighs 432 lb. A sample of coal can be weighed in the morning and the result can be used as a basis of calculation throughout

the day, if the coal continues to be of uniform quality. Whenever it appears that the quality of the coal is changing, the weight of a new sample should be taken. The following is the capacity of different sizes of buckets and baskets: 10 qt., 0.40 cu. ft.; 14 qt., 0.56 cu. ft.; 1 peck, 0.32 cu. ft.; 1 bu., 1.24 cu. ft.

If the plant does not have a platform scale, nor even a coal car, the coal can be shoveled from the bin into a large, bottomless box placed on the floor near the firing doors. As shown in Fig. 3, this box should be of at least 20 cu. ft. capacity, Then, if the weight of a sample bucketful shows the coal weighing 50 lb. per cu. ft., there will be 1000 lb. of coal in the box when level full. By means of the handles fastened to the sides, the box can then be lifted free from coal and there will be a half-ton pile on the floor ready to be fired.

With stoker firing, some type of traveling lorry scale should be used to keep a record of the coal consumption for each boiler or there should be an automatic weighing and tripping scale installed between the bunker and each stoker hopper.

Measuring Coal by Volume Is Satisfactory

In stoker-fired plants, where there are no weighing devices, the coal fed to each stoker should be measured volumetrically and the weight calculated in the same manner as previously described with hand firing. This can be done with either traveling grate or underfeed stokers by using a coal meter or even a simple revolution counter.

Every make of traveling-grate stoker has a feed gate that can be raised or lowered to regulate the thickness of the fuel bed. Knowing the height of this gate above the grate, it is a simple matter to calculate the volume of coal used per hour. In Fig. 4, a coal meter is shown attached to a traveling grate stoker. If the plant owner cannot afford weighing equipment, he should by all means provide the operators with a meter of this type.

Besides the daily check on the weight of coal fired under each boiler, the engineer should have some idea of the heat value of the coal in order to calculate the efficiency. In many plants where the general quality of the

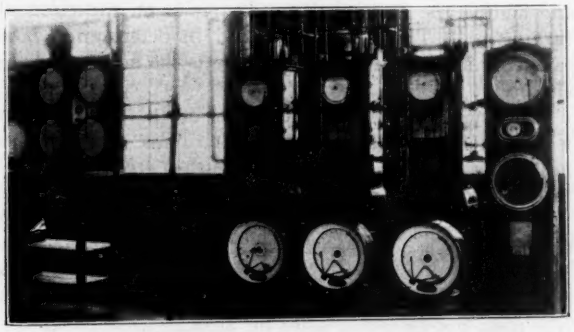


FIG. 3. THIS BOILER ROOM OF 1800 HP. HAS ALL RECORDING INSTRUMENTS AT ONE POINT

coal is the same most of the time, daily coal samples are collected in an air-tight can until the end of the week. This canful is then quartered down in the regular fashion and the final sample sent to the laboratory for proximate analysis and B.t.u.

Some of the larger plants have their own laboratories where coal and ash samples are analyzed.

If the engineer wishes to figure a heat balance, he must have an ultimate analysis. This, however, can be calculated approximately from the proximate analysis.

In plants where a large coal reserve is held in storage above ground, there is always potential danger of fire and the engineer should have one or several men trained to watch for signs of heating.

At certain times a trip around and over the coal pile may disclose nothing and yet a few feet beneath the surface there may be spots where the pile is starting to heat. Anticipating trouble will often prevent it, so that regularly measuring the temperature of the pile will tell what to expect.

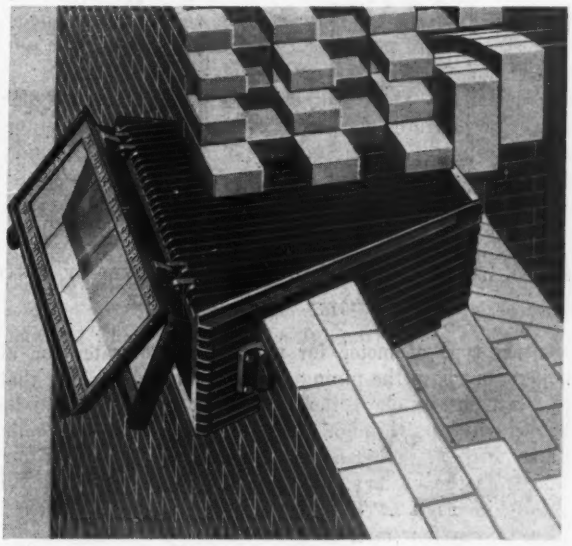


FIG. 4. HERE IS A SPECIAL DESIGN OF AN AIR-COOLED WINDOW FOR OBSERVING THE FIRE THROUGH BLUE GLASS

If there is a portable galvanometer or potentiometer in the plant, it may be carried to the coal pile and, by means of a long flexible wire connection, similar to an electric light extension cord, hooked up to a thermocouple which is to be inserted in the pile at various points. This thermocouple, of course, must be of special design to protect the hot end.

The complete thermocouple has much the appearance of a long spear with two cross arms at the end of the handle for thrusting it into the coal pile. Fires start from 4 to 6 ft. beneath the surface and, if the temperature is found to be much over 100 deg. F., the coal at this point should be removed.

Record of Water Consumption as Essential as Coal

Of equal importance with the coal weight is that of the water fed to the boiler or the amount evaporated. In normal daily operation, measuring the boiler feed water is not as accurate as measuring the steam flow from each boiler. Not all the water fed to the boiler is evaporated for, unless a special test is being conducted, a considerable amount is often lost in the blowoff.

In plants where meters are installed in the boiler feed lines, the amount of blowoff is often estimated, but these estimates cannot be close enough to be of real value. It follows, therefore, that unless meters can be installed in

the blowoff line of each boiler, the metering of the feed water will not give sufficient data to calculate results with any degree of accuracy.

If feed-water meters are not used, the evaporation should be measured with steam-flow meters. In a number of plants, the entire amount of feed water to all boilers is measured by a water-flow meter and then the output of each boiler is recorded by steam-flow meters. Some of the smaller boiler rooms with only 3 or 4 boilers have a

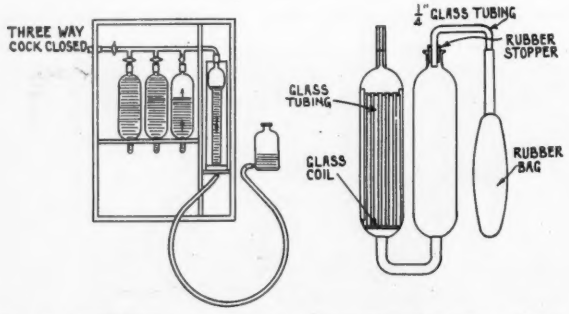


FIG. 5. ESSENTIAL PARTS OF A MODIFIED TYPE OF ORSAT GAS ANALYZER ARE SHOWN HERE

Venturi type of meter for measuring the water for all boilers, but have the piping arranged in such fashion that, if a test on any one boiler is desired, the water from the heater will pass through the meter and then to the boiler under test. The other boilers are then fed by an auxiliary line from the heater. Such an arrangement of piping is shown in Fig. 2. The steam output of each boiler is measured by flow meters.

Figure 3 shows the arrangement of recording meters in the boiler room of the same plant referred to in Fig. 2. To the right is the feed-water meter, in the center are three CO_2 recorders with the steam-flow meters underneath and to the left is a panel for six recording gages registering steam pressure and temperature, feed-water temperature and three for flue gas temperature of each boiler. At the top there is a small clock and at the upper right-hand corner, mounted on a small separate panel, is a large indicating gage for steam pressure.

Treated Water Should Be Kept to Standard by Tests

Operators should know more about the feed water than the mere fact that it is a fluid to be pumped into the boilers.

Daily observations should be made and, if there is much mud or sediment in the water, it should be removed by settling tanks or filtration. If the water is bad, a softener should be installed and an operator on each shift made responsible for its successful operation. Treated water should be tested regularly for alkalinity, causticity, hardness and excess of lime.

Considerable difference of opinion exists as to the correct ratio of alkalinity, hardness and causticity in properly treated water. According to some authorities, the causticity should be from two to three times the hardness and the alkalinity from one and a half to two times the causticity. If too little lime is used, the causticity will be too low, the hardness and alkalinity too high and scale will result. If too much is used, the causticity will be too high. Where insufficient soda ash is used, the hardness is too high, alkalinity too low and also scale is formed. Where too great a quantity of soda ash is used, priming and other troubles result.

Alkalinity and causticity are tested with a standard solution of sulphuric acid. A standard soap solution is used for testing for hardness and a silver nitrate solution may also be used for determining whether an excess of lime has been used in the treatment. The following are accepted methods of testing:

Alkalinity: To 100 cubic centimeters of treated water, to which there has been added sufficient methylorange to color it, add a standard 1/10 normal acid solution, drop by drop, until the mixture is on the point of turning permanent red. At first, the standard acid solution added, the red color, which shows quickly, disappears on shaking the mixture and this color disappears more slowly as the critical point is approached. The number of cubic centimeters of the standard acid solution used, multiplied by 50, equals parts per million of alkalinity as calcium carbonate.

Causticity: To 100 cubic centimeters of treated water, to which there has been added one drop of phenolphthalein dissolved in alcohol to give the water a pinkish color, add the standard 1/10 normal acid solution, drop by drop, shaking after each addition, until the color entirely disappears. The number of cubic centimeters of the standard acid solution used, multiplied by 50, equals parts per million of causticity as calcium carbonate.

The alkalinity may be determined from this same sample tested for causticity by coloring it with methylorange

TOTAL HARDNESS, IN PARTS PER MILLION CA CO_3, FOR EACH 0.1 CUBIC CENTIMETER OF SOAP SOLUTION WHEN A 50 CUBIC CENTIMETER SAMPLE IS TITRATED

Soap Solution C.C.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	--	--	--	--	--	--	--	0.0	1.6	3.2
1.0	4.8	6.3	7.9	9.5	11.1	12.7	14.3	15.6	16.9	18.2
2.0	19.5	20.8	22.1	23.4	24.7	26.0	27.3	28.6	29.9	31.2
3.0	32.5	33.8	35.1	36.4	37.7	38.0	40.3	41.6	42.9	44.3
4.0	45.7	47.1	48.6	50.0	51.4	52.9	54.3	55.7	57.1	58.6
5.0	60.0	61.4	62.9	64.3	65.7	67.1	68.6	70.0	71.4	72.9
6.0	74.3	75.7	77.1	78.6	80.0	81.4	82.9	84.3	85.7	87.1
7.0	88.6	90.0	91.4	92.9	94.3	95.7	97.1	98.6	100.0	101.5

and adding the acid until the sample is on the point of turning red. The total acid added in determining both causticity and alkalinity in this case is the measure of the alkalinity.

Hardness: 50 cubic centimeters of the treated water is used for this test. The total hardness, in parts per million of calcium carbonate for each 1/10 cubic centimeter of soap solution, when the 50 cubic centimeter sample is titrated, is given in the accompanying table. The soap solution is added a little at a time and the whole violently shaken. Enough of the solution must be added to make a permanent foam or lather; that is, the soap bubbles must not disappear after the shaking is stopped.

Excess of lime as determined by silver nitrate. If an excess of lime is used in the treatment, a sample will become a dark brown by the addition of a small quantity of silver nitrate, otherwise a milky white solution will be formed.

Next to the correct measurement of fuel and water, the quantity and temperature of the furnace and flue gas are of prime importance.

In modern power plant practice, several methods are employed by operators in judging combustion conditions

in the furnace. The first and most common is that of observing the color of the furnace gases and the condition of the fuel bed.

For this purpose, boiler furnaces are usually provided with peep holes or observation doors. Good combustion is indicated when the temperature of the gas reaches the point where a bright red or white transparent condition is maintained.

With hand firing, after green fuel has been thrown upon the fuel bed, the gases rising from it are streaked with opaque gas, indicating that not all of the combustible has been ignited. After passing the bridge wall, this gas should become transparent as indicated above.

It is, of course, impossible for the operator to observe these color changes with the naked eye and, for this reason, a violet-blue glass is used. As seen through this glass, incomplete combustion is indicated by dark streaks through which the opposite side of the furnace cannot be seen, while complete combustion is indicated by a clear lavender gray color.

With stoker firing, there are not periodic changes in the quality of the furnace gases as with hand firing. With a given load there is a steady evolution of gases after acceptable combustion conditions have once been established and the operator need not watch the color of the gases as closely. It is important, however, that the condition of the fuel bed be watched rather closely. Variations in the texture of the coal, moisture content and air pressure at different points may cause thin spots or holes to form in the fuel bed. Usually these holes cannot be seen without the aid of blue glass.

Special Device for Observing Fire Is Boon to Operators

In most cases, when observing the fire, operators find the small peep holes or observation doors originally designed for this purpose filled up with slag and they are forced to throw open the side or front doors. They then attempt observation with a piece of blue glass held in the hand or fastened to the visor of a cap, but are soon forced away by the intense heat, while all the time cold air is rushing into the furnace.

To observe conditions properly, a special window, which may be installed in any furnace wall, has been designed and is now on the market. This is shown in Fig. 4. The frame is of cast iron and the blue glass in the outer door is protected by common glass in the inner door. A circulation of air from either natural or forced draft keeps all parts cool.

Probably the best method of determining the completeness of combustion is by volumetric flue gas analysis, particularly the carbon dioxide (CO_2) content of the flue gas. In a large number of boiler rooms, this is done by various type of CO_2 recorders and indicators.

These machines are important adjuncts to successful furnace operation and no boiler room should be without them or their equivalent, such as an air-steam flow-meter. In cases, however, where the CO_2 and furnace temperatures are high, the excess air will be low and there may be traces of carbon monoxide (CO) in the flue gas. Most CO_2 recorders will not determine this constituent, neither will they give the amount of oxygen present. For this reason, one of the various types of modified Orsat gas analyzers, such as shown in Fig. 5, is a valuable piece of apparatus to have around the boiler room. Besides determining the gases which cannot be found with a recorder, it is used as a standard to check the accuracy of recorders.

In Fig. 6, one of the lastest types of modified Orsats is shown in the foreground to the left, ready to check the CO_2 recorder to the right of it. The Orsat is so well known to most boiler room operators that little description need be given.

It consists essentially of three pipettes which are connected at the top through glass stop-cocks or metal valves to a common header or manifold. A side view of one of these pipettes is shown to the right in Fig. 5. The manifold leading to the pipettes is connected to a graduated burette or measuring tube. The bottom of the burette is connected by means of a long piece of flexible rubber tubing to a leveling bottle.

Space cannot be devoted to details of the method of operation, since whole books have been written on the subject. Probably the most authentic information may be obtained in Bulletin 97,—Sampling and Analyzing Flue Gases,—issued by the Director of the Bureau of Mines, Washington, D. C.

Readers may be interested in a little kink in Orsat operation which is not generally known. It has been found that, by adding a small amount of acidified methylorange solution to the water in the burette, a rose-red color is obtained which serves two useful purposes. The red color

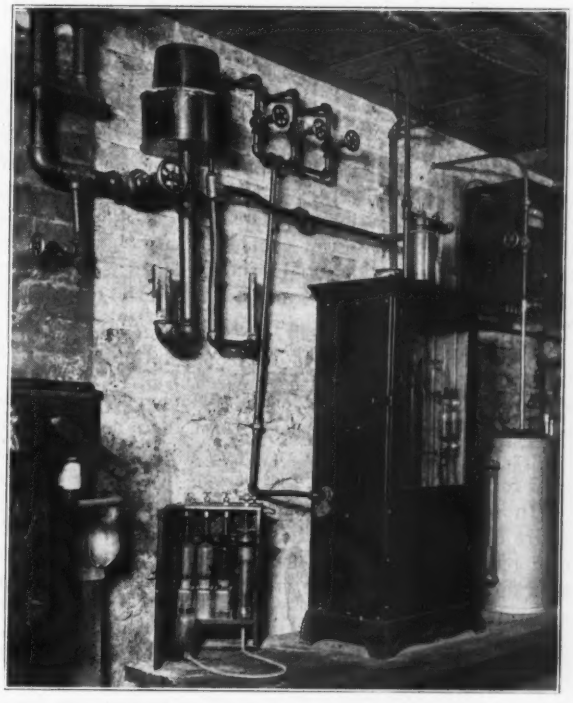


FIG. 6. IN THE FOREGROUND TO THE LEFT IS A TYPE OF ORSAT USED TO CHECK THE CO_2 RECORDER NEXT TO IT

of the water makes it much easier to read the level in the burette and the methylorange being chemically known as an "indicator" will turn yellow, if any of the alkalies in the CO_2 or O_2 pipettes are inadvertently sucked over into the burette.

A well-known combustion engineer once said, although in somewhat stronger terms, that anyone with ordinary intelligence can analyze a gas sample but it requires a

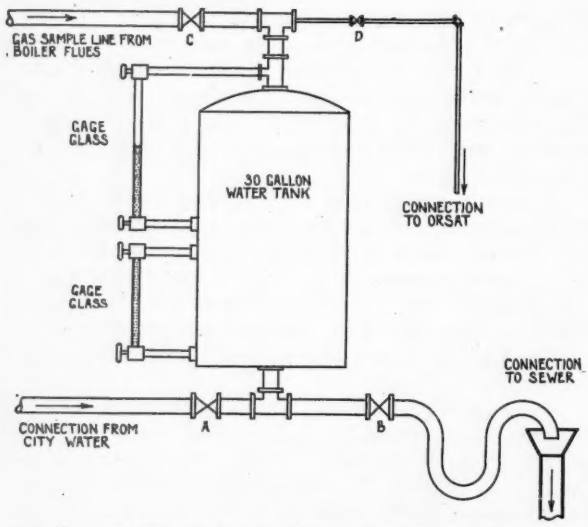


FIG. 7. ARRANGEMENT OF TANK AND PIPING FOR OBTAINING PROLONGED GAS SAMPLE

trained man to get the sample. Most operators will shove a gas sampling pipe into the furnace or flue without any thought as to whether the sample they are getting is representative of what the fire is actually doing. A common error, particularly in obtaining samples of flue gas, is to fail to observe air leaks which dilute the sample.

Be sure the sampler is in the center of the path of gases and that there are no air leaks between the point where combustion has been completed and the point where the sample is taken. A single open-end pipe is usually better than one with perforations, since the holes nearest the suction take in more gas than those farthest away. After a point has been found where a representative sample may be taken, the operator should be sure that his sampling line has been thoroughly aspirated and is free from air. Also, each time a new sample is taken, the line should be thoroughly purged of the old sample.

Grab samples are to be discouraged unless they are taken every few minutes. The best way is to erect some sort of sampling tank where the gas may be slowly collected over water for periods of 15 min. to an hour, or even longer. In Fig. 6, at the right, is shown a small tank used for collecting a sample in periods of an hour or less.

In some instances, a sample has been taken over an entire 8-hr. shift, the results of the sample being considered representative of the firing ability of the fireman on that shift but this practice is of doubtful value. Such an apparatus is shown in Fig. 7.

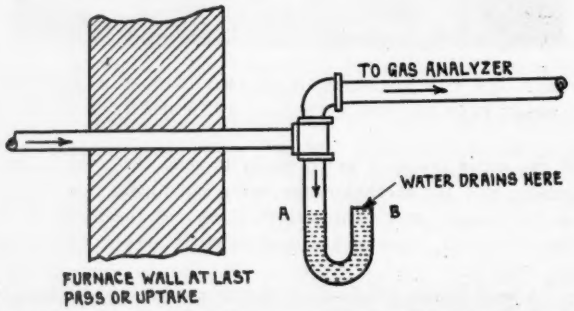


FIG. 8. SIMPLE METHOD FOR AUTOMATICALLY DRAINING CONDENSATE FROM FLUE GAS LINES

To collect the sample, first see that valve B is closed; then open A and admit water to the tank. Valve C should be kept closed to keep air from being pushed back into the sampling line, but valve D must be open. When the tank is full, shut off the water at A, close D and open C. Then open B wide and allow about ¼ to ½ of the water in the tank to run out, thus aspirating the line of air. Fill the tank again and then with the water shut off at A and valve D closed, open C wide, and open B just enough to regulate the flow in any time desired. To get the best results, it is always best to have a needle valve at B in order to provide close regulation.

Ordinarily, it is not possible to obtain gage glass in lengths over 24 in. and, therefore, to observe the flow of water at various levels in the tank it is necessary to provide two gage glasses.

In the outlet of the tank to the sewer is placed a U-tube which serves as a seal against air getting into the tank, in case the operator misjudges the speed of flow and allows all the water to run out of the tank.

Automatic Drain Eliminates Trouble

Flue gas always contains water vapor in greater or less amounts, depending on the moisture and hydrogen content of the fuel. This condenses outside the furnace when the gas sample enters the line and often restricts the flow of the sample to such an extent that the collection of a uniform sample is prevented. Figure 8 shows a simple scheme to drain off this water as soon as formed. Just outside the furnace, at the point where the gas sample is taken, a standard pipe tee is bullheaded on the sample line with the two side connections in a vertical plane. At the top, the sample line is connected to the CO_2 recorder or other gas analyzer, while at the bottom a connection is made to a piece of pipe formed in U-shape with the short leg B about 12 in. long. This U-tube is then filled with water and the gas sample started. Water will rise in A to a height equivalent to the amount of suction, say 6 or 8 in., but as the vapor in the gas condenses, it will fall on the upper surface of the water in A, will soon

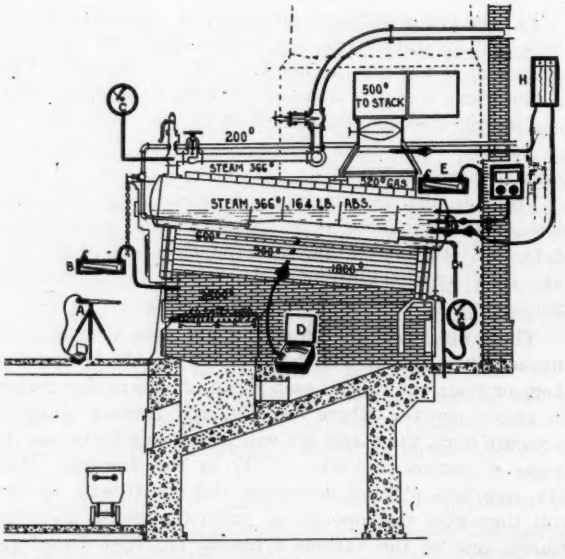


FIG. 9. DIAGRAM SHOWS PROPER LOCATION OF CONNECTIONS FOR IMPORTANT INSTRUMENTS

fill B to the top of the tube and will then drain off as fast as it forms. This sort of drain is automatic and requires no attention.

Connection-Diagram of Important Instruments

In Fig. 9 is shown a diagram which gives the proper location for the connections to several important instruments for the determination of correct operation of the boiler and furnace. The instruments may be mounted on one or more panel boards in convenient locations such as shown in the photographs at the beginning of this article. In Fig. 9, A is a pyrometer for determining the temperature of the fuel bed or of the gases just above the fuel bed; B is an indicating draft gage for over-fire draft; C records the boiler pressure; D is a portable pyrometer used for obtaining temperatures at different points in the setting; E is an indicating draft gage for the last pass, or sometimes, the uptake. Sometimes the connections at B and C are run to the same gage. F is a CO_2 recorder or indicator taking a gas sample from the last pass or, in some cases, the uptake; G is a recording thermometer in the blow-down line to give the chief a record of the number and duration of the blow-down periods; H is a flue gas temperature recorder for the last pass and uptake. In Fig. 10, curve A shows the range of flue gas temperatures which recent tests have found to be the average for several of the better known makes of boilers. Curve B was plotted from data taken from Mark's Mechanical Engineers' Handbook. In general, if temperatures exceed those given in Curve A, it is high time to look for leaky or faulty baffling or dirty tubes.

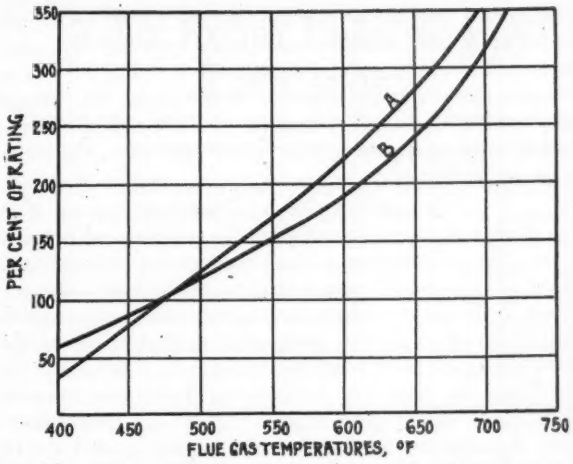


FIG. 10. CURVES SHOW FLUE GAS TEMPERATURES FOR AVERAGE OPERATION

Although not as important as some of the instruments listed above, smoke indicators and recorders are useful and, where possible, engineers will find it advantageous to install a device of this nature.

Boiler Room Management

Organizations for Small and Large Plants, Qualifications of Men and Methods of Handling Them

IN DISCUSSING the subject of boiler room management it will be convenient to consider first, management in a small boiler plant and second, management in a large plant. This does not necessarily mean that there is a fundamental difference between the principles of management in a small plant and in a large plant, for this would not be true. While the organization of a small boiler room may differ materially from that in a large boiler room, the underlying principles of management are the same. In both cases, the object is to operate the plant in the most efficient manner with the greatest possible return on the investment over a unit period of time. The success of any organization depends not so much upon its structure or its mode of operation as upon the executive and organizing ability of its director. This is a general statement and applies to any type of organization; whether it be that of a boiler room, of a corporation, of an army or a navy, it makes no difference, the success of any of these is largely the result of one man's directing genius.

In a small plant the chief engineer is usually in direct charge of the boiler room as well as the engine room and the auxiliaries. All problems of control, operation and repair, all buying and selecting of fuel and supplies, all hiring of men is directed to his attention and he is held directly responsible for the efficient operation of the plant. Usually, in plants where the equipment is modern and in good condition, one man will have no difficulty in maintaining efficient supervision over the plant. As the size of a power plant increases, however, the details of management multiply rapidly and, if the chief engineer understands his job, he will no longer try to attend to all the details himself but will delegate a portion of his authority to one of his assistants or other subordinate.

Where there are one or more assistant or watch engineers, the management of the boiler room is given to them. In a fair size plant, for instance, where there are three watch engineers in addition to the chief, one watch engineer is in charge of the prime movers, one in charge of the boiler room and the third in charge of the auxiliaries. While in this case the actual problem of purchasing supplies and hiring men is still left to the chief engineer for final decision, he is not hampered with all the details of direct supervision.

Where the plant is sufficiently large to justify the services of a water tender, the operation of the boiler room is placed under his supervision. He usually acts as head fireman and reports directly to the chief engineer.

In large plants the organization is more complex. Here the chief engineer can no longer attend to even the purchase of supplies and be held directly responsible for repair and operation, and the boiler room is in charge of the boiler room superintendent. He has the same degree of responsibility that the chief engineer has in the small plant, except that his jurisdiction does not extend beyond the boiler room. He usually has reporting to him, one or more assistants, who in turn are responsible for operation during their respective watches.

The boiler room superintendent has no fixed watch and no fixed post as his duties are in connection with the boiler room as a whole. All matters concerning fuel and supplies used, hiring of personnel and similar matters are decided by him and he is held responsible to the chief

engineer of the station for the efficient operation of the boiler room. He is concerned largely with the inspection and analysis of reports and charts and applying the results towards increasing the efficiency of the plant. The details of this work in a large station are done by a staff of technically trained engineers who report directly to the boiler room superintendent.

Qualifications of Personnel

As was the case in considering the organization in boiler rooms, the qualifications of the personnel for various duties depend to a considerable extent upon the size and character of the plant. Recent years have witnessed numerous improvements in boiler plant equipment tending to decrease manual labor, increase capacity and efficiency and facilitate the control of operations. These improvements have reduced the number of men needed for a given output, but the greater complexity of the machinery and the increased value of the output per man have made it, more than ever before, vitally important that the men down the line who actually operate the boilers, not only thoroughly understand the machinery and processes over which they exercise control but that they feel an interest in these processes.

It is impossible, of course, to pay firemen wages which would enable us to hire men who understand the complex theories of thermodynamics. Even if such men could be had at regular firemen's wages they would be a poor investment for, by the time they had learned the practical side of firing, they would lose interest in their work and a man, no matter how skillful or how learned he may be, is useless on work in which he takes no interest. It is necessary, therefore, to recruit our boiler operating force from among men having limited educational advantages.

Of course, the man in charge of the boiler room must be a skilled engineer, one who has studied the art of producing steam as thoroughly as the factory manager has studied his particular business. For a boiler plant is a manufacturing plant; the raw material is the fuel and water used in the boiler and the finished product is the steam delivered to the engines or to whatever process for which it may be used. It is the boiler-room engineer's job to produce the greatest amount of steam from a given quantity of coal with the least expense.

To achieve this result, the man in charge must possess a thorough knowledge of boilers, furnaces, stokers and other mechanical equipment, he must understand the process of combustion and should be familiar with the characteristics of various kinds of fuel. He should know the fuel requirements of certain types of stokers and furnaces and should be able to make certain tests to know whether his equipment is operating at its highest efficiency. He should possess a knowledge of the relation of the boiler plant with respect to the rest of the power plant or the manufacturing plant as a whole and should have the faculty of making quick decisions in times of emergency. In short, he should be thoroughly familiar not only with the practical side of boiler room operation and equipment but should be conversant with all the theoretical principles underlying its operation.

Between the boiler room chief and the lowest class of labor used in the boiler room, the employees should possess intermediate qualifications. It is not necessary that a fireman in a modern plant be a full fledged combustion engineer, but he should possess a thorough knowledge of the mechanical operations of the equipment in his care and what to do when certain conditions arise. If he is intelligent, these things can be taught him in a short time, so that an applicant for such a position need have no previous extended education in combustion engineering. This question of developing firemen is a difficult problem but at the same time one that is exceedingly interesting, for it brings up an important factor in the management of any organization, namely, the human factor.

The Human Factor

If the primary reason which influences a man in getting a job in a boiler room is because he needs money and if no inducement of interest in the job is offered, he will usually take no more interest in it than is necessary to continue his connection with the payroll. He may do his work in a fairly satisfactory manner, but it is certain that he will not lie awake nights trying to think of methods of improving operation. Man is so constituted that if he is to do a thing well, it is essential that he take an interest in that thing. One way to gain a man's interest in obtaining good results in boiler room practice is to show him how to get them. If we treat the fireroom force to learned lectures on thermodynamics and the theory of combustion, they may come away remembering a few such terms as CO_2 and B.t.u., but the information will be useless to them. Few men, however, cannot learn by being shown repeatedly. The way to teach a fireman to operate with low excess air is to check his gas analysis and then show him where the excess air is coming from and how to correct the trouble. By repeated checks of the gas analysis, together with observations of the fire in his presence, and with explanations of the reason for what has occurred, he will soon be able to maintain his fires in a good condition. Some authorities go so far as to say that a fireman taught in this manner will soon get so he can analyze the gas with his eye nearly as well as the chemist with his Orsat. Unless frequently checked, however, the eye like any other instrument, gets out of calibration.

In the plant which contains numerous recording instruments, it should be impressed upon the men that those instruments are not there for the purpose of giving the boss a check on what the men are doing. Explain the use of the various instruments and get them interested in them. In this way he will soon learn to regard the instrument as a friend, not as a spy.

Each man should be given a certain amount of responsibility. This will make him more important in his own estimation and will instill in him an effort to prove worthy of that responsibility; he will feel more a part of the organization.

In many plants it has become the practice to hold weekly meetings of the power plant force where their common problems are discussed. If any man has a plan, a suggestion to offer, or a grievance to air, he has the opportunity to do so at these meetings. This plan has worked out satisfactorily in many plants and has brought about a more intimate relationship between the operators themselves, as well as between the operators and the management.

A factor of considerable importance in keeping the men satisfied and interested in their work is the matter of providing them with comfortable accommodations and resonable amount of labor-saving equipment. Various investigators of personal efficiency have shown that fatigue has a deleterious effect upon the quality of the work

turned out. This fact is of importance to power plant work, where the quality of work is of paramount importance, while quality is of slight value. In the case of firemen attending hand-fired furnaces, numerous tests are on record plainly indicating that as fatigue grows, although the ability to shovel coal into the fire door does not appreciably diminish within reasonable limits, the quality of combustion becomes steadily poorer.

Fatigue is not always the result of overstraining the muscles; in fact, it has been pointed out that the greatest proportion of occupational fatigue is of nervous origin. In his book, "Mastering Power Production," Walter N. Polakov discusses this subject in considerable detail. In cases of mechanically-stoked boilers, Mr. Polakov shows that physical fatigue plays a subordinate role, whereas factors of nervous and mental origin obviously predominate. It is significant to note that the monotony of work in fire rooms equipped with stokers whose motions are hardly perceptible, where the silence or monotonous humming is seldom broken and illumination usually best adapted for slumbering meditations, has a most ruinous effect on the economy. The feeling of weariness and fatigue arising from this deadening monotony makes long hours for the firemen, not only nerve racking, but highly extravagant from the viewpoint of economy. Installation of instruments, requests for log keeping and brighter lighting alone have produced marked improvements in efficiency. Such measures alone, however, cannot be depended upon as they themselves will lose their stimulating effect. Intellectual awakening, training, competition, sporting spirit, bonuses and other forms of incentives are more effective and, if inaugurated with thoughtfulness upon a thorough analysis of all circumstances, will remain effective.

Rewards for Special Accomplishment

Bonus systems, extra rewards for special accomplishment and other methods of compensating the workmen for increased effort, if properly applied and if based upon reasonable standards, have proved of considerable value in many boiler rooms. It must be understood, however, that the success of any plan of this nature is dependent upon a spirit of co-operation between the management and the workmen. The management is compelled to accept its share of the responsibility and must keep in touch with the latest developments of boiler room practice. It is useless merely to offer the man a bonus or increased pay for extra effort if no attempt is made to show them how they can increase their output or improve their work. According to Polakov, when the men are simply told to do better and then left to struggle and solve the problem in order to receive a promised reward, it is a sign of weakness of the administration, a case when management fails to manage. Such methods shift the responsibility for securing better results on the men, but it does not likewise give them the necessary authority to adjust and control all influential factors.

Another essential is a proper appreciation on the part of the management of the value of improved work of the men. If, due to the result of the inauguration of a bonus system, the men earn a fair percentage over their normal wage, the management reduces the rate for extra skill, all the benefits of the system will be lost immediately and production will not only decrease but the management will lose the respect of all its employes.

Boiler Room Records Pay Dividends

Equipment Instruments and Data Required for Records to Determine Costs and Aid Operation

NO BOILER plant can be properly operated without a record kept continuously up-to-date of its performance, failures and repair of equipment, inspections made, conditions observed and recommendations made by inspectors. Such a record is of great value: first, in establishing and maintaining a standard to be obtained in operation; second, as a means of preventing accidents due to failure of equipment; and, third, in determining responsibility and giving credit to the men in charge for plant conditions. It is estimated that 2 per cent saving will pay for a complete installation in one year and that in the average plant these meters will effect a saving of 10 to 15 per cent of the coal bill.

Performance records consist of data gathered at regular intervals during the day from which costs can be determined and changing physical conditions of the plant observed. Most of these data are gathered hourly and recorded on a properly ruled report sheet, although in many plants, as far as they are available, recording type instruments are used and do not require hourly readings, but the charts are gathered up once a day and constitute part of the daily record. Inspection and repair data should take the form of a journal to which quick reference can be made and which contains a complete history of each important piece of equipment in the plant, describing in some detail the troubles which have been encountered and the repairs which have been made.

Performance records are used for two principal purposes: one is to determine costs and the other to aid operation. In considering the data and instruments needed for establishing costs, it is necessary to determine all factors which enter into the cost of steam generation.

Instruments for Supplying Cost Data

Equipment required for furnishing cost data consists principally in scales for weighing coal and ash, meters for measuring water and steam, also meters for measuring the steam or power used by boiler room auxiliaries. The other data necessary for determining costs are secured from the accounting department and, in many cases, the boiler room employes are not required to fill in these figures.

Following is a list of the items which are ordinarily given in a complete monthly report for the purpose of determining cost of producing steam: Coal used, cost of coal, water used, cost of water, water evaporated, ashes made, coal received during the month, coal on hand, water evaporated per pound of coal, steam used by auxiliaries, power used by auxiliaries, cost of oil waste and supplies used in boiler room, cost of labor, cost of repairs and renewals, cost of obsolescence and inadequacy, cost of insurance, cost of taxes and rent, cost of interest on investment, cost of management, total cost per thousand pounds of steam, cost of coal per thousand pounds of steam. If these data are kept month by month or week by week, comparison of the various records will permit a close check on plant economy.

Operating records, which are of aid to the engineer in the operation of his equipment, record at intervals usually of an hour the conditions existing in the plant,

so that any variation may readily be seen and corrections, if necessary, be made without having the plant run for any length of time in an inefficient manner.

In planning a system of records to aid the operator, it is well to consider that wherever a physical, chemical or energy change takes place, there is a chance for a loss and each change should be studied in detail to determine what items, if any, affecting the change should be kept for comparison. If any variation likely to occur affects the overall cost an appreciable amount or endangers the safety of the plant, that item should by all means be made a part of the daily record.

In the boiler room we have losses to the ash pit, radiation, flue gases, so it is well to study conditions which cause these losses and aid the fireman by providing him with instruments which will direct him in the handling of his boiler furnace.

The log sheet in the boiler room should, therefore, give a record of the following items, readings taken preferably every hour: Amount of coal burned per boiler; pounds of feed water fed to the group of boilers or to each individual boiler; per cent CO_2 in the flue gas; flue gas temperature; steam pressure and temperature; time and duration of safety valve blowing; pounds of steam delivered by each boiler; furnace draft; differential draft; feed water temperature; pounds of ashes made; the hours of operation of each boiler; time and amount of blowoff; time of dusting tubes; rate of fuel feed, either speed of stoker or speed of pulverized fuel feeder; water level in the boiler and, in addition to these items in the daily report sheet, it is well to note the kind of coal being burned, the amount of coal burned per square foot of grate surface per hour and the pounds of steam generated per pound of coal burned. Thus, on this daily report sheet, would be given the information which is required for determining operating costs when the prices are secured from the bookkeeping department.

Considerable equipment is required for keeping such a record. Coal scales are necessary, preferably of a type for weighing coal to each boiler. Feed water meters are needed, either one for the group or one for each boiler. Gas analysis instruments, preferably of the recording type, or some form of instrument which will indicate directly the amount of excess air are extremely valuable. If the boiler is large, individual gas analyzing instruments should be employed, but in smaller plants one recorder is generally used which gives the CO_2 in the chimney gas but can be attached to any individual boiler which seems to be giving trouble.

Flue gas temperature should be taken preferably by a recording thermometer in the boiler breeching of each boiler. Indicating steam gages must of course be provided, but it is also advisable to have recording gages also and a recording thermometer. Steam from each boiler should be measured by a steam flow meter, preferably of the recording type. Draft in the furnace and differential draft can be measured satisfactorily with a draft gage of the indicating type, if, however, the engineer of the plant wishes a continuous record of the amount of draft in the furnace, this instrument must be of the recording type. Feed water temperature should be measured by means of a recording thermometer located in the discharge from the boiler feed pump. Where an economizer is part of the installation, a thermometer should also be placed in the feed line from the economizer to the boiler.

Ashes should be weighed, correction being made for the amount of water used for cooling, at the time they are removed from the ash pit which may be one, two or three times a day. The amount of water discharged through the blowoff is sometimes metered on its way from the blowoff tank to the sewer, though in most cases it can be satisfactorily estimated by noting the lowering of the boiler water level during the time that the blowoff valve is open. Stoker speed is usually measured by means of a revolution counter, the readings of which are taken each hour and from this the number of revolutions of the crankshaft or the travel of the grate may be determined. Water level is indicated by means of a gage glass, but recently plants are installing boiler level indicators and recorders.

Use of Operating Records

In comparing records of boiler performance from day to day, it is well to keep in mind that any condition in a power plant may be classified under one of the following general heads: non-controllable, semi-controllable and controllable. Under the first heading comes the weather, given equipment and other things which must be accepted whether desirable or not. Semi-controllable conditions are those which are not absolute but may be changed somewhat by discrimination in selection or treatment, such as the quality of fuel, quality of water, load curve per unit, etc. Controllable conditions are those which the operator has absolutely under his control, such as steam pressure, draft, thickness of fuel bed, division of load among units, time of blowing down boilers, flue dusting and the like.

In operating records showing these changing conditions, the task of the engineer is to determine what conditions he can change to meet the non-controllable conditions and then give general instructions to his operating force in order that the highest overall efficiency may be obtained. When this has been done, the record has served its purpose and any further records are of value only in keeping a check on the plant operation and in maintaining equipment in best condition.

Many engineers, as soon as possible after a plant has been put into operation, endeavor to establish a standard as high as is possible to attain with which they compare their daily record. This standard is frequently based on tests which are made for efficiency and when a unit does not come up to standard operating conditions, its performance is studied and conditions throughout the day are noted so as to determine just where the cause of lowered efficiency may be.

Starting with the plant as a whole, the usual plan is to draw curves, extending them each day, of the principal overall results and non-controllable conditions.

In many plants it has become the daily practice to figure out a heat balance and in this way determine where the losses occur. Comparing these losses from day to day will guide the boiler room engineer in his study of conditions which are changing and in his instructions to operators as to the frequency of performing certain operations, such as tube dusting, blowing down and inspecting boilers and other matters of routine which vary considerably in different plants.

One great danger in the planning and use of records is to make them so complete and complicated that the information which they contain will not be used to the fullest extent. Record keeping then becomes a burden and, unless the data is used, it is of little value in the daily operation of the plant.

Midwest Power Conference, Jan. 26 to 29, Will Have Great Interest

SUCCESS of the Midwest Power Conference to be held in the rooms of the Furniture Club of America, 666 Lake Shore Drive, Chicago, Jan. 26 to 29, is assured, as is evidenced by the interesting subject for papers and the list of noted engineers who are to present them.

Registration will begin at 10 o'clock Tuesday morning at the Furniture Club, the registration fee of $1.00 covering expense of all technical meetings. The registration badge also gives season admission to the Chicago Power Show, which is being held during the same week.

At the opening session, 2:30 Tuesday afternoon, W. L. Abbott, President of the American Society of Mechanical Engineers, will act as chairman. The address will be by Samuel Insull, who will speak on Some Comments on the Power Development of the Mississippi Valley.

Wednesday morning's session at 10 o'clock will have as chairman, B. F. Lyons, President of the Great Lakes Section of the National Electric Light Association, and will treat of power generation and distribution.

The first paper by Daniel W. Mead, consulting hydraulic engineer of Madison, Wis., will be on What We Can Expect from Hydraulic Power in the Middle West.

At 10:30, H. Birchard Taylor, Vice President of The William Cramp & Sons Ship and Engine Building Co., Philadelphia, will speak on Changing Viewpoints in Hydraulic Turbine Practice.

At 11 o'clock, R. F. Schuchardt, electric engineer of the Commonwealth-Edison Co., Chicago, will present a paper on Superpower in the North Central States.

At 11:30, G. C. Neff of Madison, Wis., Chairman of the Rural Electric Service Co. of the N. E. L. A., will review progress in Rural Electric Service.

Wednesday afternoon beginning at 2 o'clock will be devoted to recent advances in coal-saving methods of operation and will be presided over by Homer Niesz, President of the Western Society of Engineers, Chicago.

William S. Monroe, President of Sargent & Lundy, Consulting Engineers, Chicago, will present the first paper on Recent Developments in Electric Power in the Chicago District.

At 2:30, C. F. Hirshfeld, Chief of the Research Department of the Detroit (Mich.) Edison Co., will outline Present Practice in the Burning of Pulverized Fuel.

At 3 o'clock, H. W. Brooks, Consulting Engineer of the Fuller-Lehigh Co., will present the results of his investigations on By-Product Processing of Coal.

At 3:30, Dr. R. E. Hall, Physical Chemist of the Bureau of Mines Experiment Station, Pittsburgh, Pa., will give, in a paper on Boiler Water Conditioning with Special Reference to High Operating Pressure, the conclusions of a research extending over 3 yr.

Thursday morning session will have James H. Herron, President of the Jas. H. Herron Co., Consulting Engineers, Cleveland, Ohio, as chairman. This session will deal especially with operation and economy in industrial plants.

The first paper, at 10 o'clock, will be by Paul L. Battey, President of Battey & Kipp, Engineers, Chicago, on Layout and Equipment of Industrial Plants.

At 10:30, Messrs. G. B. Warren and J. H. Keenan of the Research Department, General Electric Co., Schenectady, N. Y., will describe a recently developed machine for Testing Steam Turbine Nozzles by the Reaction Method.

At 11 o'clock, C. F. Scott, President of the National Safety Council, will speak on Safety and First Aid in Industrial Plants followed by a First Aid demonstration by an expert team of workers from one of Chicago's utilities.

At 11:20, L. F. Harza, Hydro-Electric and Hydraulic Engineer, Chicago, will present a paper on Planning and Operating Industrial Hydraulic Plants for Best Economy.

At 11:50, J. Paul Clayton, Vice President of the Central Illinois Public Service Co., Springfield, Ill., will speak on Purchased Power for Coal Mines in Illinois.

Thursday afternoon will be devoted to inspection trips, the main groups going to the Crawford Plant of the Commonwealth-Edison Co., to the printing plant of the Chicago Tribune and to the Underwriters' Laboratory. Entry can be arranged to other plants which visitors at the Conference may wish to see.

Thursday evening at 7 o'clock, a dinner meeting will be held at which men of national reputation will speak on The Effect of Wide Power Distribution and Availability on the Social and Economic Life of the Country.

Friday morning, the session at 10 o'clock, devoted to Oil and Gas Power, will have Dean A. A. Potter of Purdue University, Lafayette, Ind., as chairman.

The first speaker, Max Rotter, Vice President and Engineer, the Busch-Sulzer Bros., Diesel Engine Co., St. Louis, Mo., will treat of The Diesel Engine in the Industries.

At 10:30, Samuel M. Vauclain, President of the Baldwin Locomotive Works, Philadelphia, will give a paper on The Diesel-Electric Locomotive, Its Present Status and Performance and Future Possibilities.

At 11 o'clock, a paper by Allen F. Brewer, Consulting Engineer, The Texas Co., New York, will deal with The Economics of Oil as a Boiler Fuel.

At 11:30, H. H. Clark, Industrial Gas Engineer, The Peoples Gas Light & Coke Co., Chicago, will speak on The Present Status of By-Product Gas Furnace Practice.

Friday afternoon will be available for inspections, trips being arranged as desired by visitors. Some suggested points of interest are the Western Electric Co.'s plant at Hawthorne, the new plant of the International Harvester Co., the Chicago Avenue Pumping Station and possibly one of the large electric locomotives of the C., M. & St. P. Ry. will be on view, also the Diesel-Electric Switching Locomotive on test by the C. & N. W. R. R.

Plans are under way for entertainment of ladies during the days of the conference, including shopping trips, the Field Museum, bridge-luncheon and a theater party.

At all meetings of the Conference, time and opportunity will be given for discussion of papers presented, and it is requested that those desiring to take part in the discussion notify G. E. Pfisterer, Secretary of the Committee of Arrangements, 517 Monadnock Building, Chicago, Ill.

EDITORIAL COMMENT

Our New Year's Greeting to You

During the past year many things for which the industry has been striving have been accomplished but the ultimate end has not been and never will be reached. Desires and hopes do not necessarily start or end with the beginning of a new year but we do find it convenient, in recording events, industrial accomplishments and scientific discoveries, to associate them with the year in which they occur. So we plan our important undertakings by years.

Each reader of this magazine probably has a goal set for which to strive during the year 1926, the field is broad, the opportunities are many and as varied as individual desires. With proper choice and constant endeavor, every man should reach his goal, if not in one perhaps in two or three years.

Whatever beneficial results you may desire to accomplish, we, the editors of Power Plant Engineering wish you happiness and success in the undertaking.

Boiler Economy, the Power Show and the Manager

Boiler room equipment, of many new or improved types, and methods of decreasing the cost of burning fuel, were the outstanding features of the fourth annual Power Show, recently held in New York City. These are the things in which the power plant world, both central station and industrial, has been deeply interested during the past year. It must not be imagined that no work has been done with the prime mover end of the plant, for that is far from the truth. But in the boiler plant, especially the industrial installation, the savings possible by improved methods and a few new pieces of equipment are so quickly obtained and in such comparatively large amounts, compared with those possible in the turbine room, that the attention of the management is more easily attracted to the boiler house.

By installation of air preheaters, for example, it has been possible to decrease by as much as 5 or 10 per cent the cost of making steam. By simple changes in the methods of handling the fires, the total steam cost may often be reduced 4 or 5 per cent. Yet after the prime mover is installed—a turbo-generator, for instance—its operating characteristics are practically fixed by the manufacturers and if it is properly operated under all the steam conditions for which it is designed, it is seldom possible to reduce its steam consumption by even 0.5 per cent. Moreover it requires the entire resources of a great turbine-building organization to make some small change in the design or construction that will get such a small increase in economy or a decrease in cost. The same thing holds true, in general, for the steam engine and the internal combustion engine, on both of which considerable development work has been done that was not apparent at the Power Show. The savings that can be made in the average boiler room, however, can with proper presentation be made so apparent to the management that few sensible executives will neglect the opportunity to make those savings.

This, then, was the principal value of this year's Power Show: it gave the visiting engineer a bird's-eye view of the improvements in boiler room practice during the past twelve months and showed how these improvements can be utilized to reduce power costs. Yet it is not the engineer himself who must be convinced of the value and economy of the various improvements and new styles of equipment. It is usually the management of the plant that cannot see the necessity for spending money on the power house. It is to be regretted that each engineer visiting the Power Show could not have been accompanied from booth to booth by the non-technical executives who are so often in direct control of the expenditures for his power plant equipment and fuel.

New Standard of Boiler Rating Needed

From time to time the question has been agitated as to why we should continue to rate our boilers on the basis of 10 sq. ft. of heating surface per boiler horsepower. It is purely an arbitrary practice, without good reason and, among power plant operators of the old school, has probably caused considerable loss in operating economy.

In our American practice we say that a boiler is rated at 600 hp. if it has 6000 sq. ft. of heating surface and that it is operating at rating, if it is evaporating 3.45 lb. water per sq. ft. of heating surface. In several instances, older engineers have been prone to consider the amount of water evaporated at rating as about the maximum allowable and they believed that there would be lower efficiency, if there was much of an overload. Otherwise, they said, why didn't the manufacturer give the boiler a higher rating, if it was meant to be operated at heavier loads? With plants of appreciable size, this resulted in the need for a large number of small boilers instead of a few larger units, as we find today. Losses resulting in the operation of so many small boilers are obvious. If there had been no such thing as boiler rating in terms of horsepower but merely a statement of the number of square feet of heating surface, some of the old time operators would have felt free to operate boilers at greater evaporation than 3.45 lb. water per sq. ft. of heating surface. They would have continued to fire coal until the boiler was producing as much steam as they needed or until the maximum grate capacity was reached.

Many engineers disapprove of rating a boiler on the basis of horsepower but do think that a statement of the square feet of heating surface is somewhat acceptable. Apparently British engineers avoid even this. In referring to our method of boiler rating, a British engineering journal states as follows: "American nomenclature in this respect is not worthy of imitation and the custom in this

country of calling the rating of a boiler the number of pounds of high-pressure steam per hour which the makers guarantee it to produce is not only much more logical but has a certain analogy in the way the word 'rating' is used in connection with electrical machinery."

Such a method of rating, however, is likely to cause trouble when comparing the evaporation of the boiler with that of other boilers in capacity tests. Suppose that the manufacturer stated that a certain boiler would deliver 50,000 lb. of steam at 200 lb. gage pressure, we would have no means of comparing this boiler with others unless we knew its size. At first thought, therefore, a statement of the number of square feet of heating surface seems necessary. But, in light of recent developments, even the heating area has little significance.

Besides this, if we adopted the British method of boiler rating, we would, without doubt, experience the same trouble that the British are now having. In the article previously mentioned, the author states that "competition between boiler makers has become so keen that there is a temptation to rate boilers at higher and higher evaporative capacities, so that the purchaser may be attracted by apparent cheapness."

It appears that the term "horsepower" has been seized upon whenever engineers lacked suitable expression of ideas. It was originally used as a unit of work, then as a unit of evaporation, and finally as a unit of boiler capacity.

In the expression of the expenditure of energy as work we already have brake horsepower and indicated horsepower. Any further use of this term leads to confusion and the time is ripe to eliminate the use of horsepower in boiler practice.

Since a B.t.u. is the fundamental unit involved in the calculation of heat exchange in any process, why not express boiler activity in terms of heat absorption? As an average, 10,000 B.t.u. would be an acceptable figure for the heat value of a pound of fuel and this figure should admirably serve as a unit of performance in boiler practice.

It has always been assumed that it requires 10 sq. ft. of heating surface to produce one boiler horsepower, but modern methods of boiler and furnace design have so improved conditions that the same evaporation can now be effected with a half to a quarter that amount of heating surface. In fact, there has recently been announced the remarkable achievement of producing 70,000 lb. of steam with only 2000 sq. ft. of heating surface. Expressing this in the usual terms, it means that 2000 boiler horsepower was produced with 2000 sq. ft. of heating surface, or .1 boiler horsepower for each square foot. In terms of orthodox boiler rating this is equivalent to 1000 per cent of rating. This new steam generator has exactly the same area of heating surface as the ordinary 200 hp. boiler, but one certainly cannot think of a boiler which produces 2000 hp. as a 200 hp. boiler.

Rating a boiler in terms of horsepower or even in square feet of heating surface, therefore, has ceased to give any indication of the work it will do.

Acknowledgment

Back of all engineering information of value are experiments and data secured in practical application of equipment. All this information does not originate in one plant nor in one factory. On the contrary, sources of industrial information are scattered throughout the entire world and it is, at times, with great difficulty that data desirable for the progress of the industry can be made available to all those who can use them advantageously.

Fortunately for the power plant industry, secrets in power generation are almost impossible and, more fortunately, the leaders in the field are broadminded enough to recognize that engineering information held secret is detrimental to development. It is this spirit of cooperation, the inclination of those engaged in the industry to give out facts which they have obtained, that has made it possible for the editors of Power Plant Engineering to gather and present in this issue information which they trust will prove of value to the men on the "firing line."

Conditions have not permitted direct credit throughout the issue to the sources from which data were secured, so we take this opportunity to acknowledge the assistance given us by individual engineers, manufacturers of power plant equipment and technical associations, who have generously assisted us in the preparation of this issue, and in this way publicly to thank them for their part in making the issue what you find it.

The Master Operator

Samuel Butler once wrote a book in which he described a country where machinery had been developed to such a degree that the machines finally became the masters and the people the slaves. This, to be sure, was a far fetched conception and one not likely to transpire, yet when we note present-day developments in automatic machinery and calmly think about future possibilities we sometimes wonder whether the author of Erewhon was so far off the track.

The visitor to one of our modern central stations finds it strangely deserted. Coming into the building, he sees endless streams of coal on long belts swiftly, silently flowing into the plant, apparently without the aid of human hands. In the boiler room, between rows of enormous boilers, only the steady drone of motors is heard—the bustle and glare of the old-time boiler room has disappeared. Instead of a score of men attending a few hundred horsepower of boilers, in the modern station two or three men care for thousands of horsepower. The same is true of the turbine room; here, usually in a chamber of cathedral-like proportions, one or two men casually guard the huge generators sending hundreds of thousands of kilowatts out into the world. What has happened in these plants? Surely these few men cannot supervise the operation of millions of dollars of equipment without the aid of some unseen power?

Electricity is the great unseen power which enables these few men to operate the station—electricity is the master operator who watches all the multitudinous details of mechanical operation, who runs the stokers, measures the steam flow, records the gases in the stack. Electricity keeps tab on the speed of the generators and the temperature of their windings. Electricity opens and closes the valves and protects the station from damage in case of accident, in short, electricity does everything that the operators used to do but does it much better.

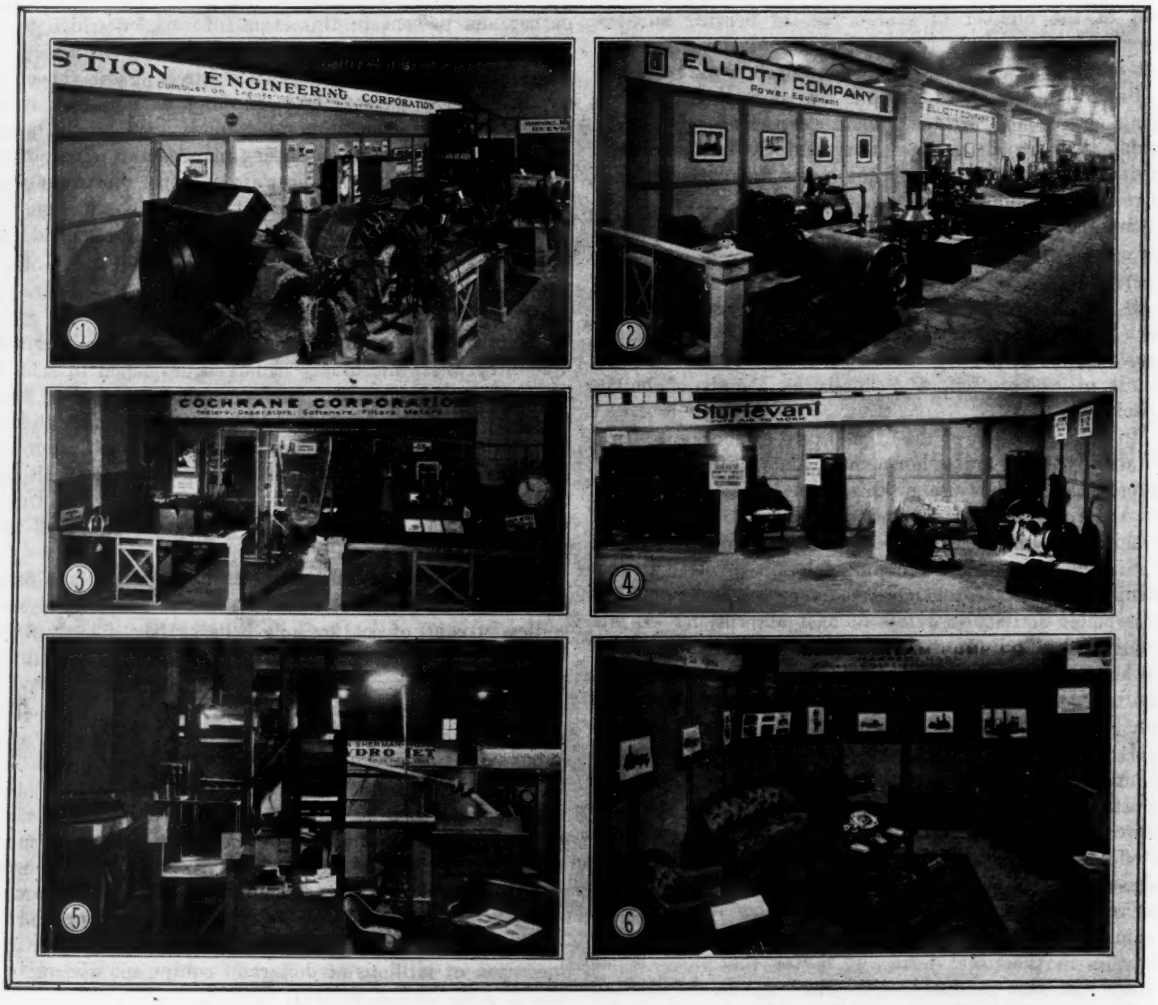
Someone has said that the future central station will operate without a man in it. Perhaps that too is a far fetched statement but we know of certain small plants that operate that way so even that we would not say is impossible.

Fourth Power Show Surpasses Predecessors

PULVERIZED COAL AND COMBUSTION APPARATUS ARE CENTERS OF INTEREST AT FOURTH NATIONAL EXPOSITION OF POWER AND MECHANICAL ENGINEERING

PROGRESS IN THE power plant field during the past twelve months was shown in a most complete display of all types of power plant equipment, by over 400 manufacturers, at the Fourth National Exposition of Power and Mechanical Engineering, held at the Grand Central Palace, New York City, from Nov. 30 to Dec. 5, 1925. In the number and diversity of exhibits, in attendance and in enthusiasm of both spectators and exhibitors, this exposition was far ahead of its predecessors.

Viewing the Exposition as a whole, the outstanding characteristic was the large number of working models and full size pieces of apparatus. These included economizers, superheaters, stokers, coal pulverizers, air compressors, large motor operated valves, and several showings of combustion control apparatus in operation. Working models included a coal pulverizing plant, several model boilers,



PULVERIZED FUEL EQUIPMENT, LEAD COATED ECONOMIZER AND OTHER INTERESTING BOILER EQUIPMENT WERE DISPLAYED

Fig. 1. Combustion Engineering Corp. displayed its "Imp" unit pulverizer, couch burner, single and group feeders, air heaters, fin tube water-cooled wall and other products. Fig. 2. Deaerators, heaters, stream flow valves, tube and surface cleaners and the Kerr Turbine were attractively shown by Elliott Co. Fig. 3. A sectional working model of the new strainerless cone type filters, connected to suitable measuring instruments was the feature of the exhibit of Cochrane Corp. Fig. 4. B. F. Sturtevant Co. showed the Type Y lead coated extended surface economizer, the air economizer and various types of fans and blowers. Fig. 5. The hydro-jet for sluicing ash was shown in actual operation by the Allen-Sherman-Hoff Co. Fig. 6. An improved design of four-stage centrifugal boiler feed pump was the center of interest at Warren Steam Pump Co.'s Booth.

conveying equipment and coal and ash handling devices.

Among the interesting items displayed were new types of unit coal pulverizers, a new type of water-cooled furnace wall and several types of mechanically and electrically operated combustion-control systems.

Combustion apparatus occupied a large place in the

Exposition. There were five showings of air-preheaters. Economizers were well represented and included one novelty in the form of a steel economizer with lead-coated tubes. The rapidly increasing importance of pulverized fuel was indicated by many exhibits of all types of apparatus used in its preparation and burning. These included pulverizers, feeders, transport systems, and burners. There was also a feeder and meter for delivering and measuring pulverized coal from storage bins to burners. There were many stoker exhibits of hand and power operated types. Oil burning equipment was presented by eight manufacturers. Novelties in this field included burners for the use of either pulverized coal or oil. Developments in gages, meters, and recording instruments were mainly in the direction of securing easier reading instruments and in eliminating errors of reading and calibration.

In the accessory field there were many new developments. These included electrically-operated soot blowers, non-collapsible float steam traps, air-cooled soot blowers, water columns, filters, regulators, pump governors, and the like. Among the exhibits of valves and fittings was a testing outfit for long-time duration test of metals under continuous load and at high temperatures. Valves for high pressures with several types of motor operation attracted attention in this class of exhibits. One manufacturer displayed safety valves for use up to an operating pressure of 1200 lb.

Pulverized fuel equipment showed several new designs of apparatus and various improvements in existing apparatus. A small model of the recently-announced well-type furnace, using gas-fired burners to show the turbulent flame action produced, attracted much attention at the booth of Fuller-Lehigh Co. where was exhibited a complete assortment of pulverized fuel equipment. A model of the standard type of Randolph waste heat dryer also attracted considerable attention. A Fuller-Kinyon pumping system was set up, with its complete automatic switchboard control and signaling system, to demonstrate the remote controlling of the coal transport system by means of the bin level indicators, electrically controlled, pneumatically operated switching valves in the transport lines.

The feature of the Riley exhibit was the Atritor, the new type of unit pulverizer they have just placed on the market. The first effect is now equipped with swinging hammers instead of pegs and the second effect consists of pegs as before, but with certain improvements which allow them to be easily and quickly replaced. Hot air for drying is admitted to the first effect of the Atritor. The well known Multimix Burner was also shown by the Riley Stoker Corp.

The booth of the Combustion Engineering Corp. was a center of interest. A section of the well known fin-tube type of water-cooled wall was shown, together with the method of carrying the weight of a brick wall on the fin tubes. Refinements in the construction of the air-cooled hollow wall were shown, together with examples of both simplex and group type feeders, and the well known Lopulco burner. A C-E air heater, an Imp pulverizer, driven by a direct connected motor with variable speed transmission, and sections of the Coxe and Type E stokers were also presented. A complete full size Couch burner, with a capacity of 6000 lb., was also on exhibition. A miniature model of the Raymond mill, fully equipped for operation, also drew considerable attention.

At the booth of the Bailey Meter Co., one of the most interesting items exhibited was a new type of furnace wall just being put on the market. This is a water-cooled wall, consisting of tubes to which refractory blocks are bolted. These blocks consist of refractory material with an iron block backing, which is bolted or clamped to the tubes of the wall. Furnaces equipped with this new type of furnace wall are already in operation at Richmond Station. Another item of interest was a new type of pulverized coal feeder recently developed by the Bailey Meter Co. This feeder is designed to eliminate flooding and variation in the head of coal in the bin above the feeder. The standard Bailey meter boiler control was shown in operation.

Furnace Engineering Co. exhibited the Simplex unit pulverizer, the model shown having a capacity of 12,000 lb. per hr. This unit pulverizer incorporates a Dings magnetic separator and other mechanical features designed to produce convenient operation and great mechanical strength.

At the booth of the Erie City Iron Works, a unit pulverizer of 1000 lb. per hr. capacity was exhibited. The casing of this machine was raised to allow inspection of all parts of the interior and several photographs and installation print showed typical installations of this equipment. The pulverizer was shown direct connected to a 3½ hp. d.c. General Electric Co. motor. A large colored picture showed a section of the Erie City Iron Works, three-drum, inclined water tube boiler.

The Pennsylvania Crusher Co. showed a one-third size model of a new type of armor frame single roll crusher. This is the first time that the Pennsylvania Crusher Co. has exhibited a single roll crusher in a working model. The model has a capacity of about 12 to 15 t. per hr., while the full sized crusher of this type will handle about 60 t. per hr. A shear pin device is provided on this single roll crusher to stop the crusher in case a piece of mine timber enters. Coal is crushed against a plate held by springs and designed to throw out any tramp metal in the coal. This crusher is suited for small power plants and for laboratory crushing and will crush to ½ in. size or less. A 1/6 size model of the standard Bradford breaker was also exhibited.

Aero Pulverizer Co. exhibited the Aero unit pulverizer, with direct connected electric motor drive. This pulverizer has self-alining roller bearings and a complete lining of manganese steel. A magnetic separator is provided on the feed mechanism and the construction throughout is of heavy steel. Preheated air connections are provided to supply air with the coal in amounts as high as 85 per cent of the total air required for combustion. The pulverizer exhibited had a capacity of 2500 lb. per hr. Photographs and illustrations showed models of the Aero pulverizer in capacities of 500 to 20,000 lb. per hr.

Bethlehem Steel Co. had in operation a working model of the new Bethlehem pulverizer.

It was announced at this booth that one type of this pulverizer, with a capacity of 6½ tons per hour, would be operated with a power consumption of 9½ hp. per ton of coal. The pulverizer rolls crush the coal against a horizontal plate and the exhausting fan and the method by which coal is fed to the pulverizing zone, have been designed to reduce power consumption.

The Air Preheater Corp., successors to James Howden Co. of America, Inc., exhibited the Howden-Ljungstrom air preheater. This preheater is made in any capacity that may be desired in modern boiler practice, and is made up of a rotating element inside a cylindrical case that is divided through the center. Flue gas passes up one side of this partition, and incoming cold air passes down the other side, the heat from the flue gas being transferred to the air by the rotation of the element.

The flat plate type of air preheater was shown by Combustion Engineering Corp. and B. F. Sturtevant Co. exhibited the air economizer, another design of a plate type of air preheater.

Stokers and Grates

A new mechanical drive for the Jones side-dump stoker was exhibited by Riley Stoker Corp. This is a spiral gear drive, chain driven from an electric motor, and was designed to meet the desire of many engineers to eliminate the steam-actuated stoker mechanism and to use as many electric drives as possible throughout the plant.

A full size Huber stoker, designed for a 1000 hp.

NEW TYPES OF MOTORS, ELECTRICAL EQUIPMENT AND MECHANICAL DRIVE TURBINES AROUSED INTEREST

Fig. 7. A unit pulverizer of improved design was shown by Erie City Iron Works. Fig. 8. New types of mercury arc rectifier, the latest induction type flow meter, mechanical drive turbine and improved motors attracted attention at General Electric Co.'s booth. Fig. 9. Fairbanks, Morse & Co. featured ball bearing motors and centrifugal pumps. Fig. 10. Bayer Co. had on display its new totally enclosed balanced valve-in-head soot blower, an addition to standard types. Fig. 11. Circuit breakers, small turbines and new types of instruments were shown by Westinghouse Electric & Mfg. Co. Fig. 12. The method of installing Hytempite was shown by Quigley Furnace Specialties Co., Inc., together with Quigley Triple-A solutions and the therma-shock test.

boiler, was shown in operation at the booth of the Flynn & Emrich Co., This stoker was designed for high ratings, using natural draft, and is operated by two hydraulic motors, one for feeding coal from hoppers onto a coking shelf and pushing it down to the grates after it has coked, the other motor advancing the fuel bed. The stoker is built in sections, both as regards depth and width and can be adapted to any size of boiler furnace.

A complete working model of a double retort Detroit underfeed stoker was shown in operation by Detroit Stoker Co. The stoker exhibited was rated at about 350 hp. and a model of the gear case assembly with parts of the casing cut away showed the gears and internal construction of these parts.

Two interesting working models of grates were shown by Neemes Foundry, Inc., Troy, N. Y. The first was a working model of the standard shaking and dumping grate; the second, a working model of the grate known as the Buckwheat burning grate, for small anthracite coal. The latter is equipped with slotted type grate bars and pinhole dump plates. The anthracite burning grate has a closed mechanism, whereas that on the regular model is open. On the anthracite burning grate, also, is the standard lock box arrangement and dump plates are lipped with a special lock. This lock enables sections to be dumped while the others are locked, so that as the dumping sections go back in place, if a clinker lodges between the two, the pressure will not be able to dump the locked section.

Combustion Control

Probably the most interesting feature of the various displays of combustion control and boiler control equipment was that full-sized commercial pieces of equipment were shown in actual operation. Bailey Meter Control was shown, the various indicating and recording instruments being mounted attractively on panels. This system employs the steam flow-air flow principle, steam pressure serving as a control to regulators, not only the amount of fuel and air fired, but also their ratio. In this system, when changes in fuel are required, the control devices increase the air faster than the increasing fuel feed and decrease it slower than the decreasing fuel feed, thus keeping air always in excess.

In the mechanical type of automatic control shown by Carrick Engineering Co., variations in steam pressure are transmitted through a mercury column to a master control. The latter adjust fuel feed and air supply; changes in fire conditions are compensated by an overfire draft regulator operating on the damper. These controls are mechanical, but a new type of this equipment has been developed in which the mercury column variations are transmitted electrically to various motors with suitable controllers that adjust the various elements of the combustion system.

To show the operation of the Smoot combustion control system, a small gas-fired boiler was set up in conjunction with standard control equipment. The boiler was equipped with air-volume, gas-volume, damper and stoker regulators, controlled by a master regulator. A CO_2 indicator was connected to the stack and showed how the products of combustion could be regulated. When the master was set for a definite CO_2 value, the system maintained this value practically constant over wide load variations. The system also maintained steam pressure within a fraction of a pound over wide changes in boiler rating.

Steam Turbines

Several interesting specimens of steam turbines were exhibited, mostly arranged with reduction gears for industrial work, pump drives, fan drives and the like. A 100 kw. mechanical drive steam turbine was exhibited by General Electric Co., designed for direct connection to centrifugal pumps and the like through herringbone gears. This turbine is furnished with either one, two or three stages, depending on the requirements of the work. A geared governor is used and an oil pump supplies oil to this governor control and also to the bearings. The turbine is furnished for condensing or non-condensing service, with the appropriate soft or carbon packings. The emergency governor is separate from the main governor. The turbine casing is split through, ground joints are used in all cases, and all connections are in the bottom of the casing, thus making for convenience, inspection and maintenance.

The De Laval Steam Turbine Co. showed several small turbines. One of these, a velocity stage turbine, was driven by the blast of an electric fan, impinging on the blades of a second fan belted to the drive shaft. This second fan was thus revolved and drove the turbine wheel slowly through a worm reduction gear. Worm gear reduction gears of several types were shown with their casings removed.

Terry Steam Turbine Co. showed a 700-hp. turbine for use at 600 to 750 lb. steam pressure, equipped with all steel casing and operating at any back pressure up to 125 lb. A 120 hp. Terry turbine, with Terry reduction gears, was also on exhibition, together with several models of the Terry couplings. Photographs of the Terry multi-stage turbo-generator sets for industrial work were shown in sizes up to and including 100 kw. These turbines can be furnished for back pressures as high as 135 lb., or in various mixed pressure, condensing or non-condensing and bleeder types.

Moore Steam Turbine Corp. exhibited single-stage turbines adapted for driving boiler feed pumps, forced draft fans and other auxiliaries. These turbines are of the three row velocity stage type. All stationary parts are horizontally split, assuring accessibility, and they are made in sizes from 5 to 750 hp. Types of multi-stage turbines, bleeder and mixed pressure turbines were also shown, together with the Moore double helical reduction gears.

Centrifugal and Reciprocating Pumps

Kingsford motor-driven, side suction, centrifugal pumps and Kingsford centrifugal automatic sump pumps were shown by Kingsford Foundry & Machine Works. Special attention was also called to the Kingsford-Webster water tube longitudinal drum boiler, equipped with equalizing tubes from the rear headers to the drums.

At the exhibit of the Bethlehem Shipbuilding Corp., Ltd., several models of the Bethlehem-Weir type boiler feed pump were of interest. The model shown is made in capacities up to 1500 gal. per minute and for service up to 800 lb. pressure, in a single stage, and is equipped for turbine drive. A new type of general service pump,

in sizes from 2 in. to 22 in. discharge, with capacities from 35 to 17,000 gal. per minute, was featured; this also is a single-stage pump for work at 100 lb. pressure. The Pervac condensate pump was shown, as well as a model of a duplex double-acting motor-driven power pump for general water supply service and low pressure boiler feeding. Considerable interest was also shown in the Bethlehem-Weir corrosion detector and the Bethlehem-Dahl oil-burning furnace front.

An attractive feature of the exhibit of C. H. Wheeler Mfg. Co. was a Radojet air pump with combined inter and after-condenser, used with closed boiler feeding systems. Various other type of the Radojet air pump were shown, together with the Radojet augmenter and the Froud type absorption dynamometer.

The Warren Steam Pump Co. displayed a complete line of Warren motor-driven centrifugal pumps and one or two types of reciprocating pumps. An interesting item was the four-stage centrifugal boiler feed pump for direct-connected steam turbine drive. The feature of the pump is the balanced design to eliminate mechanical strains and prevent leakage.

Engineers visiting the show were interested in a large centrifugal motor-driven vacuum pump, exhibited by Nash Engineering Co. This pump had a capacity of 1520 cu. ft. per min., and was driven by a 90-hp. General Electric Co. synchronous motor, direct connected. With certain changes, the same type of machine is supplied as a centrifugal compressor.

A recently developed line of direct-connected, motor-driven centrifugal pump, completely equipped with ball bearings, was featured by Fairbanks, Morse & Co. Various specimens of its standard types of centrifugal, reciprocating and power pumps were shown by Worthington Pump & Machinery Corp. A 2¾- by 4-in. self-oiling power pump was shown and a 3-hp. gasoline engine completed the exhibit.

At the booth of Frederick Iron & Steel Co., various models of centrifugal pumps were featured. One of these was a 4-in. single-stage, double-suction centrifugal pump, capacity 600 g.p.m. against 70-ft., head driven by 15-hp. motor. A 2-in. three-stage, type R pump, for industrial work, was shown direct-connected to a 35-hp. steam turbine. For a small house service pump, a 30-g.p.m. pump was shown, driven by a 1-hp. gasoline engine direct-connected.

Among the interesting items at the booth of Wheeler Condenser & Engineering Co. was a two-stage centrifugal condensate pump, designed with a pressure seal to prevent air leakage.

Electrical Equipment

A double wound rotor squirrel cage motor of the ball-bearing type, designed for direct voltage starting was shown by Fairbanks, Morse & Co.

Visitors to the booth of General Electric Co. were much interested in an exhibit of mercury arc rectifiers which the company is now placing on the market. A type MS, form L rectifier for industrial truck charging was shown, with improvements leading both to improved operation and lower cost. A new type of 250-amp. mercury arc, rectifier, rated at 62 kw., 250 v., was also exhibited for the first time. Several new types of motors with various improvements were also of great interest. The new type TS synchronous motor, designed to run at high speeds for belt driving and for low speeds for direct driving and made in sizes as low as 25 hp., was of interest. The new type CB general purpose motor for d.c. work, superseding the type RC, was shown in sizes of ½ to 200 hp. In the type KT Motor, an improvement has been made in the stator windings so that no winding is exposed. In another type of synchronous motor, the coils of the rotor have been staggered to eliminate noise and an iron reactance has been built in to aid in direct line starting.

Allis-Chalmers Co. featured the well known type AR and ARY motors, equipped with roller bearings, as announced a short time ago.

Latest types of circuit breakers mounted on panels attracted attention at the booth of Westinghouse Electric & Mfg. Co. Various models of their standard types of geared non-condensing turbo-generator units, both a.c. and d.c., were exhibited, as well as small mechanical drive turbines and d.c. direct connected generating units. The full line of Westinghouse air ejectors, with and without inter-coolers, was represented. Specimens of new type of portable and switchboard measuring instruments were shown and a varied exhibit of Micarta, material used for manufacture of gears and a variety of machine parts.

Furnace Construction

Norton Co. exhibited a section of a lateral retort stoker in its setting, showing the installation of Crystolon Brick at the clinker line and in the bridge wall. These brick were set in Norton Refractory Cement. Enameling muffles, made of Alundum, used in the vitreous enameling field, were displayed.

Botfield Refractories Co. presented specimens of work done with Adamant firebrick cement. This cement is designed for high temperature work and can be used either as a bonding material in refractory walls or as a facing material, in which case it can be applied with a brush and worked into the pores of the brick, just as paint is worked into the grain of wood.

A new model of the Detrick sectional supported side wall construction was shown for the first time by M. H. Detrick Co., Inc. Models of various types of Detrick arch construction, showing suspension and replacement details, also created considerable interest. These models were constructed of aluminum framework, using wood blocks to represent the usual refractory blocks and allowed complete detailed explanation to be made of the various materials and methods involved.

In addition to specimens of water-cooled wall construction, Combustion Engineering Corp. had on display a hollow firebrick wall showing improved methods of laying the air-cooled wall. In one instance the air space is made with gradually decreasing area around the furnace to allow for the smaller volume of air at a distance from the air inlet and the air passages to the furnace are made with a special type of S-shaped block designed to provide an indirect path from the air space into the furnace, thus giving better cooling of the inside refractories.

A new type of water-cooled wall was displayed by Bailey Meter Co. Blocks composed of cast iron with a refractory facing are clamped to water tubes, the iron serving to conduct heat rapidly from the refractory material. A solid flat wall of these blocks is produced by this method.

Working models of coal and ash handling equipment were shown in operation. Typical of the former was the

complete miniature installation of a skip hoist larry and drag scraper in operation, handling small quantities of crushed coal, shown by R. H. Beaumont Co. This miniature installation was complete in every detail and showed the convenience and ease of operation of all this equipment. The standard types of copper-steel ash hoppers, together with hand and power operated pivoted ash gates, were represented. A new type of ash sluice, designed particularly for pulverized fuel furnaces, was on exhibition. This sluice is made of unlined, hard white iron, the sluicing nozzles being fitted into the bottom of it. One interesting feature of this sluice is the provision for a gasketed, water-tight joint between the sections.

A working model of a complete Hydro-jet ash handling system was exhibited by Allen-Sherman-Hoff Co. In this system water jets feed the ash from the bottom of the ash hopper over a feeder plate into a horizontal sluice, where other water jets carry them to a sump, whence a centrifugal pump takes them to the car-loading hopper. One of the important features of this arrangement is that a horizontal sluice can be used, thus saving head room in the boiler room basement and the disposal of ash can be controlled entirely from the boiler room floor above.

Valves and Valve Control

Blowoff valves designed to resist corrosive and erosive effects were featured by the Everlasting Valve Co., the Looseat valve being especially emphasized, together with the Tandem Model X, embodying two valves under one control. A tandem blowoff valve for 300 to 500 lb. pressure equipped with planetary gearing was shown by Yarnall-Waring Co. This valve is balanced by admitting

ATTRACTIVE EXHIBITS OF COMBUSTION AND VALVE CONTROL, STEAM ACCUMULATOR, UNDERGROUND LINE CONSTRUCTION AND NEW PULVERIZER

Fig. 13. New design of water cooled furnace wall and new pulverized coal feeder were shown by Bailey Meter Co., in addition to working models of the Bailey meter control. Fig. 14. Motor operated gate valves and apparatus for making long duration constant load and constant temperature tests of metals were of interest at the booth of the Chapman Valve Mfg. Co. Fig. 15. Ruths Accumulator Co. showed a miniature installation of the Ruths accumulator and a full size regulating valve. Fig. 16. Condensation meters, underground steam line construction and a complete line of low and high pressure heating equipment was shown by American District Steam Co. Fig. 17. Chas. Cory & Son, Inc., featured signal systems, the Cory-Reony valve control and switch interlocks. Fig. 18. A working model of the new Bethlehem pulverizer was shown by Bethlehem Steel Co., Inc. Fig. 19. Gulf steam water heaters and Marion soot blowers were shown by Marion Machine, Foundry & Supply Co. Fig. 20. Bundy Steam Trap Co. called attention to the improved mechanical construction of their traps shown by working models.

pressure to all sides of a hollow piston and is furnished with a crank for extremely high pressure work. The Hovalco-Homestead combination blowoff valve was exhibited by Homestead Valve & Mfg. Co. Another feature of their display was the refinery type of valve developed for use with various viscous fluids and especially for refinery service at high pressures and high temperatures. This is a plug type valve with a fin bonnet. A globe valve was shown with a protecting skirt on the outside of the disc designed to reduce the velocity and to prevent scoring and wire drawing of the seat. This globe valve is designed for use with steam or gas.

A new type of balanced packless blowoff valve was shown at the booth of the Edward Valve & Mfg. Co. This is a lever-operated valve and possesses several features of interest to the boiler operator. A new Ferac Non-Return Valve was also shown, in addition to the regular line of steel valves for high pressures and high temperatures.

One of the important points of the exhibit of the Chapman Valve Mfg. Co. was an apparatus for making tests of valve metal, which is being done in co-operation with a committee of the A.S.T.M. This testing machine provides means for loading the metal at constant loads of 16,000 and 11,000 lb. per sq. in., at a constant temperature of 1000 deg. F., the temperature being electrically controlled. This testing work will involve testing of materials of many kinds at both low and high temperatures, under various conditions of stress, in co-operation with other manufacturers and engineering concerns, to determine the effect of temperature on metals.

Coffin Valve Co. exhibited the Kelty motor drive unit, for electric operation of valves. In this unit the motor is designed to close the valve completely before it is stopped by a multiple disc friction clutch, acting instead of a switch. This is to eliminate the necessity for final closing by hand. An automatic stop is provided to stop the valve if it becomes obstructed. Remote controls are provided. Of especial interest at the booth of Schutte & Koerting Co. was a toggle top stop check non-return 12-in. boiler valve. This was designed for high pressure service and the toggle arrangement allows it to be closed easily under these conditions.

A new type of screwed medium pressure bronze globe valve, for 225 lb. service, known as Fig. 600 valve, was featured by Jenkins Bros. A new type of disc is used with this valve, designed to eliminate wear on the seat. A bronze needle valve with a steel spindle was also of interest, and a marine check valve and various other type of marine valves were displayed.

Class XD and ID stream line flow non-return valves of a recently developed type were shown at the booth of Elliott Co. The building type of Elliott deaerator was also featured and a model of the improved Welderon receiver separator was displayed. Standard types of tube cleaners were shown, operated by air, and the action of the Elliott Co.'s air leakage meter was demonstrated.

Cookson separators of various horizontal and vertical types were shown by D. T. Williams Valve Co. Iroverso iron body, bronze mounted valves, with nickel alloy disc and seat, both reversible, for steam, water, gas and oil at 150-lb. pressure and 450 deg. F. Reverso valves of the same type but with bronze body were recommended for 200-lb. service.

The Wm. Powell Co. displayed an extensive assortment of White Star valves of the iron body and bronze body types in globe, angle, cross and check valves. The feature of the exhibit was a motor-driven steel gate valve for 400-lb. pressure, 750 deg. F. total temperature, equipped with Liberty control.

The Dean control system for remote control of motor-operated valves was featured by Cutler-Hammer Co., a working model of the Dean control being shown on a 10-in. gate valve. Another item of special interest was an exhibit of the bulletin No. 9586, three-pole overload and under voltage X starter. This was displayed in two sizes, mounted on panels to show operation under normal and overload conditions.

Several items in the exhibit of Chas. Cory & Sons, Inc., who have long been known as manufacturers of equipment for marine work, have now been adapted to stationary power plant practice. One of these is the Cory-Recony standardized unit system of valve control, of which five sizes are offered to operate valves of all types, from 2 to 60 in., for high or low pressure service. The limit switches are designed for unusually fine settings, and when the control is applied to water valves, an automatic safety stop is provided to operate in case the valve becomes blocked. Dynamic braking is used on these valves; completely equipped control stations give remote operation of the valves. A second interesting feature was a system of interlocks for circuit breakers. Third, complete signalling systems of both visible and telephone types, used in marine practice, have been redesigned and adapted to the particular conditions of stationary work.

Another type of electrically operated remote controlled valve, made in sizes from 3 in. up, was shown by Ruggles-Klingemann Mfg. Co. in addition to a pilot operated balanced valve of the single seated type, the parts of this valve being designed for removal without taking the valve off the line.

Steam and Vacuum Traps

Several improvements in steam trap construction were noted. Sarco Co., Inc., featured in their exhibit the Sarco No. 9-4 trap, a development of the No. 9-2 trap. The latter was made in sizes of ½, ¾ and 1 in., while the No. 9-4 trap is made in sizes of 1, 1¼, 1½ and 2 in. The No. 9-4 is also provided with multiple bellows and can be furnished for any angle or for straightaway service.

A large capacity trap, known as the Super-trap, was featured by W. H. Nicholson & Co. They also exhibited the Nicholson Float, designed for pressures up to 1500 lb. per sq. in. and made of monel metal, chrome nickel steel and other material, to produce a non-collapsible, non-corrosive and acid-resisting float.

The feature of the exhibit of the Bundy Steam Trap Co. was a new type of trap, incorporating several new features, such as integral casting of bowl, pipe and elbows, roller bearings and compression springs on lever fittings, improved stuffing box, and other improvements. Several types of return systems employing Bundy Traps were shown in actual operation.

The Ace steam trap, equipped with a Corliss valve, designed to insure steam and water tightness, was shown by The W. B. Connor Co., Inc. This trap is furnished with cast iron or steel body, depending on the pressure, and with bronze or monel metal valves and float, depending on the temperatures.

Several new types of condensate traps, float chambers

and balanced free-flow check valves, were featured by Atwood & Morrill Co. Since the process of bleeding steam from turbines at low pressures for feed water heating by means of stage heaters has become general, Atwood & Morrill Co. have developed reverse current valves and other fittings to conform to the requirements of this work.

Armstrong traps are now built with parts of non-corrosive heat treated chrome steel for high pressure service and were shown by Armstrong Machine Works. These traps are made with steel bodies for working pressures of 500 and 600 lb.

Models of the vertical steam separators, shown in actual operation, were featured by the Swartwout Co. In addition to this, much interest was shown in the Swartwout Rotary Ball Bearing Ventilator which was exhibited at the Power Show for the first time.

Feed Water Control

At the booth of Wright-Austin Co. the Crescent try cock for 400-lb. pressure service aroused interest. Other new items were the Brownie low water signal and a water column alarm device. A large model of a receiver steam separator, with a shell of flanged steel and forged steel nozzles for high pressure and superheat work, was also exhibited, this separator being an adaptation of standard designs to meet high pressure and high temperature conditions.

The "S-C" Regulator Mfg. Co. showed specimens of the "S-C" feed water regulator in both the single and twin generator types, made in sizes from ½ to 12 in., for pressures of 1 to 1000 lb. per sq. in. The "S-C" drainage control, for pressures from 1000 lb. down to vacuum, was displayed and Type S differential valve, for use ahead of the regulator in the discharge of boiler feed pump, also drew considerable interest. "S-C" high pressure boiler feed pump governors for 550 to 600 lb. steam pressure, and 700 to 750 lb. water pressure, together with the "S-C" air relief valve, were also displayed.

The Kieley high pressure automatic boiler water feeder was emphasized by Kieley & Mueller, Inc. This feeder derives its action from an enclosed non-collapsible cast iron float in the casing, the float actuating a centerport balanced water valve. Seats and discs are easily renewed by removing the valve bonnet only; the casing, tapped for gage glass and try cocks, may also serve as a water column.

At the booth of the Northern Equipment Co., an exhibit of the Copes feed water regulator was shown, a working model of the regulator being set up and operated. A line of equipment for 600 lb. pressure was also displayed and the adjustable port control valve attracted considerable attention.

Fisher Governor Co., in addition to their standard line of governors, called especial attention to the new type of high temperature and high pressure differential excess pressure pump governor. This is made either for turbine-driven pumps or for reciprocating pumps, with extremely heavy diaphragm cases, all monel metal trim and all steel body. These governors have been designed and built to the A.S.M.E. standard.

A sectional display model of the recently developed cone type filter, using sand and gravel with either pressure or gravity feed, was featured at the booth of Cochrane Corp. In this installation, a centrifugal pump circulated water through the filter, the flow being measured both by a standard Cochrane V-notch meter and by a pipe orifice meter. To the latter were connected Cochrane flow meters, one of these being a new type for indicating and integrating flow, at the same time recording flow pressure and temperature.

New types of spray nozzles exhibited by various companies also attracted attention. A new type of involute spray nozzle was shown by Yarnall-Waring Co. This was shown in two models, the regular, giving a high, narrow spray and the long throat giving a low, flat spray. The Spirodome nozzle of The Cooling Tower Co., Inc., is designed to produce centrifugal action within the nozzle bowl.

Piping Systems and Equipment

Forge and hammer-welded tongue and groove pipe ends with swivel flanges were shown by M. W. Kellogg Co., also a hammer welded nozzle-forge welded to the pipe, copper-plated forged pipe and Kellogg radial brick for chimney construction.

At the booth of the American District Steam Co., the item that attracted the attention of most engineers was the duplex sleeve guided expansion joint, designed for pressures up to 350 lb. per sq. in.

An expansion joint with monel metal sleeve for superheat work was featured by E. B. Badger & Sons Co. A new type of equalizing, flangeless joint for use on welded pipe line was also displayed.

Pressure and damper regulators, feed water regulators and pump governors of many types were displayed. D. H. Skeen & Co. featured the Mercon constant reduced pressure regulator. In this regulator, a liquid column is used in place of a spring or weight to balance a diaphragm against the pressure in the regulator which is to be governed. This regulator is designed to eliminate stuffing boxes, pistons and unbalanced diaphragms. Three working models of it were shown.

Step-action control, transmitted by electricity instead of by water pressure, to the device to be regulated, was the essential feature of a new type of electric pressure regulator, exhibited by Ruggles-Klingemann Mfg. Co. Instead of a pilot valve, as used with the hydraulic regulator, this electric pressure regulator employs a pilot switch. The whole arrangement is designed to permit of remote control of equipment at much greater distances and with greater accuracy than is possible with other types of regulator. Another interesting feature of this exhibit was the electrically operated remote control valve, made in sizes from 3 in. up and capable of being regulated from any convenient point. A pilot-operated balanced valve of the single seated type was exhibited, all parts of this valve being designed for removal without taking the valve off the line.

Mason No. 131 combination reducing valves were exhibited in the 8-in. size by Mason Regulator Co. These valves, which have cast steel bodies with monel trim, were shown in working models, operated by Mason No. 130-B regulators.

Oil and Water Purification and Cooling

Centrifugal purifiers for oil were shown by The Sharples Specialty Co. Several models of the Sharples Supercentrifuge were displayed, in both the open and closed types; the latter, called the Presurtite, is designed to prevent the escape of vapor from the oil while it is being purified in the machine.

The De Laval Separator Co. had an interesting illuminated drawing showing the action of its oil purifier. Several types of purifiers were on display for insulating oil, turbine lubricating oil and the like and an interesting portable model, mounted on a truck with its driving motor.

Spray Engineering Co. exhibited a new type of air filter. In this filter a number of filter cells are used, which are coated with a special viscous fluid, called Dustix. In passing through the cells, the air is broken up into small streams and the Dustix aids in holding back particles of dirt brought in with the air. The dust particles absorb the Dustix and the additional dust-collecting surfaces thus formed increases, thus gathering more dust all the time.

In addition to models of cooling towers, The Cooling Tower Co., Inc., exhibited the Type A Tang-L-Dust air filter. In this filter, the filter medium is arranged in two stages, the first built on the separator principle with vertical baffle plates, the second containing filter media on which dust is caught. Dust-coated surfaces are kept saturated with Tangelene oil by an oil pad arrangement.

BOILER FEED PUMPS, STOKERS, VALVES, NEW CONDENSER PACKINGS AND ACCESSORIES SHOWED DEVELOPMENT

Fig. 21. Various types of pumps, including the Bethlehem-Weir centrifugal boiler feed pump, were displayed by Bethlehem Shipbuilding Corp. Fig. 22. Installation of refractories with a small side dump stoker was shown by Norton Co. Fig. 23. A full size motor-driven underfeed stoker was shown by Detroit Stoker Co. Fig. 24. The Bigelow Co. showed drawings of the Bigelow-Hornsby boiler. Fig. 25. The new No. 9-4 Sarco steam trap was featured in addition to a varied assortment of its standard products by Sarco Co., Inc. Fig. 26. An operating model of the Lea weir meter attracted attention at the booth of Yarnall-Waring Co., which exhibited blowoff valves and new spray nozzles. Fig. 27. The John Crane extended funnel condenser tube ferrule was of interest at the booth of Crane Packing Co.

A recent type of the Carrier Air Washer, produced by the Carrier Air Conditioning Corp., was shown at the booth of the Buffalo Forge Co. and Buffalo Steam Pump Co. This air washer is equipped with a Buffalo pump, but no fans are needed to produce draft through it, as the draft is induced by the water sprays themselves. This washer is adapted to generator air cooling. The brass air

fin heater with blower in the back was exhibited in a 2200 cu. ft. per min. model with a heat transfer capacity of 200,000 B.t.u. per hour.

Griscom-Russell Co. showed models of the U-fin generator air cooler and the multiwhirl air cooler. Sections from the bent tube evaporators for low and moderate pressures were also exhibited. In these evaporators the tubes are initially bowed and expanded into the headers, and temperature changes cause distortion of the tubes, which cracks the scale.

Crane Packing Co. had on display the John Crane Extended Funnel Ferrules for condensers. These ferrules are designed with a deep packing space to prevent tube erosion and to correct tube vibration. A new type of endless metallic condenser ring was also shown.

Water Heating and Steam Superheating

A new type of extruded neck nozzle was on display by the Power Specialty Co. The feature of construction of this nozzle is that the extruded neck and flange are fused and welded together. Another interesting feature is the dished head now used on the end of the heater instead of the blank end formerly employed. A new type of belling expanded and a new tube cutter were shown. A hand hole plug for boilers, employing the stuffing box principle, and designed for extremely high pressure work, was of considerable interest.

The Marion Gulf Stream Water Heater, designed for industrial use and adaptable to small power plants, was featured by Marion Machine, Foundry & Supply Co. In this heater steam is applied to both the inside and outside surfaces of a film of water passing through the heater.

At the booth of B. F. Sturtevant Co., the center of interest was a section of the Sturtevant type Y economizer, with lead coated tubes and extended surface. A lead alloy is applied to the inside and outside of tubes in order to prevent corrosion and the surface of the tube is extended by discs fastened to the economizer tubes in such a way as to secure tight joints between disc and tubes. The tubes are expanded into headers of forged or cast steel. Between every group of six sections, a space is left for soot blower elements. Models of the Cindervane fan were shown, this fan being designed to remove cinders and solid matter from flue gas before it passes to the stack, and serving also as an induced draft fan. Small sizes of geared turbines and stokers for heating and industrial plants were included in the display. The Gaso-Fan, a new portable ventilating fan, driven by a three-quarter horsepower gasoline engine, both units being mounted together, was also displayed. Although this fan was designed primarily for the ventilation of telephone manholes, it is applicable wherever conditions make it inconvenient or impossible to use electric motor-driven fans.

Considerable interest was manifested at the booth of the Buffalo Steam Pump Co. and Buffalo Forge Co. in a recent type of Duplex Conoidal Induced Draft Fan with straight blades. This is designed for high efficiency and, among other interesting mechanical features, has outside water-cooled bearings entirely exterior to the fan inlet boxes.

A working model of the Bigelow-Hornsby Boiler showed one new feature in the location of the superheater behind the first bank of tubes instead of behind the second. This was exhibited by The Bigelow Co., and also showed the converging type arrangement of the heating surface and the integral steel Bigelow-Hornsby economizer baffled so that the products of combustion pass from the furnace to the flue outlet without reverse turns.

The booth of Edge Moor Iron Co. formed a point of interest for the visiting engineers. Here were shown drawings and photographs of the recently announced Edge Moor Single Pass Boiler. These drawings showed the sectional construction of tubes and headers. The integral economizer and superheater sections, the contracted gas passage through the economizer section, the location of self-operating soot blowers and the methods of controlling superheat.

Working models of the latest types of Diamond soot blowers, equipped with the new Dialoy elements for high temperature location, attracted the interest of engineers at the booth of the Diamond Power Specialty Co. Dialoy, the material used in these elements, is described as a homogeneous alloy, possessing the qualities of steel, but having in addition characteristics that prevent deterioration such as might be caused in a cast element. Another feature incorporated in the latest types of Diamond soot blowers is the automatic operation feature. Three automatic blowers were shown, operated from a time clock. The master control first actuates a special automatic steam valve, then the drain valves of the blowers, and finally the units are operated in rotation throughout the boiler.

The Bayer Co. exhibited models of their four types of soot blowers, the latest one being Model K, in which all moving parts, such as gears and cam, are housed in to keep out grit and dirt. Other models are the type R direct drive model, the model O, with geared head but without inclosed features and without balanced valve features, and the Model T geared head without the balanced valve, but with the housing feature. In addition to the double tube air-cooled element for extremely high temperatures, the Bayer Co. also exhibited a new monel metal sheathed soot blower element for high temperature conditions.

An interesting model showing a typical installation of the Ruths Accumulator, with valves, piping and control systems, was displayed by Ruths Accumulator Co., Inc. The accumulator is a device for storing steam in a tank when demand is low and utilizing it when the demand increases. This is done by putting boiling water under pressure in a tank and, by means of suitable regulating valves, decreasing this pressure when steam is needed, thus allowing some of the water to evaporate into steam. The device has had wide application in Europe and is particularly designed for taking fluctuations in industrial plants, allowing boilers to be fired at constant rating.

A working model of the Tracyfier, showing a full size cross-section of the device in actual operation to separate moisture from air, formed the center of interest at the booth of Andrews-Bradshaw Co. Many engineers were interested, also, in an extremely simple arrangement of chemical apparatus in this booth, in which a demonstration was given of how foam is produced in boilers and how the cellular structure of this foam, caused by various substances in the water, causes moisture and entrained solid matter to be carried over with the steam.

One of the recently developed water or liquid level gages was shown by Republic Flow Meters Co. In this indicator, a mercury column balances the head of liquid to be measured, and the varying height of this liquid is transmitted to the indicating or recording device through electrical contacts in the gage body. These contacts connect

with the standard Republic indicating and recording instruments by an electrical cable, thus enabling the instruments to be placed at any convenient point, regardless of the position of the gage itself.

The recently developed Ace Water Level Indicator was exhibited by The W. B. Connor Co., Inc. This indicator employs a forged steel float, varying with the water level, and the motion of this float is converted by a series of low voltage transformers located in the steam space of the column, and these varying electrical impulses cause a row of lights to burn bright or dim, according to the motion of the float. Extremes of high and low water are indicated by red lights. The column of this indicator is built in accordance with the American standard for 400 lb. working steam pressure and the electrical parts are designed for operation at the temperatures prevailing at this pressure.

The Bristol-Derr water level gage was shown by The Bristol Co. In this instrument the difference in temperature between steam and water level spaces is caused to produce small electrical impulses which are transmitted by wire to an indicator at any convenient point. The long distance electrical transmitting and recording system was also shown by working models, together with recording thermometers and pressure gages and instruments combining records of both pressure and temperature. Another interesting improvement exhibited consisted of a high speed attachment for the strip recorders to magnify the record during abnormal conditions.

The Brown Instrument Co. featured an electric CO_2 meter, an illuminated dial indicator with 12-in. scale, a new model recording CO_2 meter, driven by an electric clock, and the recently developed Brown liquid level recording gage, the construction of which eliminates a diaphragm.

A new chart hub was featured by the Foxboro Co., Inc., a large size model of it being shown. A new liquid level gage of the differential pressure type, for liquids under pressure, and adapted to steam boilers or other pressure tanks, was featured. A porous sleeve wet bulb for the recording psychrometers was displayed.

Republic Flow Meters Co. also showed a new type of CO_2 recorder. The recorder is placed as close to the boiler as possible. It analyzes gas once a minute and the potash is renewable every three to four months. The connection with the indicating and recording instruments for this CO_2 recorder is made wholly electrical, thus eliminating the pipe connections often necessary.

Uehling Instrument Co. called especial attention to their new waste meter, which is a combination temperature and CO_2 recorder. They also exhibited a new type of recorder which enables the barometer reading and vacuum reading, on a turbine or other machine, to be recorded on one chart, thus affording a convenient means for determining true vacuum.

Improvements have also been made in the induction type GE flow meter of the General Electric Co. In this meter a varying transformer action, produced by variation in the height of mercury around an insulated transformer element, produces a current change which is measured and calibrated in pounds or gallons, or whatever unit may be required, by the standard indicating and recording instruments. A working model of this meter was shown. The mechanical type of GE flow meter was also shown, with new cobalt magnets, external adjustments, chamber change for calibration and the addition of temperature and pressure elements with the flow elements.

A new diaphragm type of indicator, in which no mercury is required, was displayed by Builders Iron Foundry. Other types of Venturi tubes and Venturi meters for steam, ammonia, boiler feed water and condensate measurement were attractively mounted on panels at this booth.

Pointer type mechanically operated draft gages, of a recently developed model, were shown by Paul B. Huyette & Co. They had, in addition, the standard line of boiler feed water gages and try cocks, Hayes CO_2 recorders, P.P.H. gage glass protectors, Ajax damper regulators and the like, General Electric Co. electric flow meters and a complete exhibit of the standard safety water columns of the Reliance Gauge Column Co. These columns were shown with nickel alloy seats, discs, and seamless floats for high pressures.

At the booth of The Permutit Co., the Ranarex mechanical combustion indicator was exhibited and explained. The operation of this instrument for the indication of CO_2 depends on the difference between flue gas and air; this difference in density is measured mechanically and indicated on a dial at the top of the instrument, at the same time being continuously recorded on a chart.

The Ashton Valve Co. called attention to their master pilot gage for indicating steam pressures to all operators in a power plant. This is furnished with dials 18, 24, 30 and 40 in. in diameter, as may be required. Any graduation that is necessary can be furnished, the usual arrangement being to have the normal working pressure at the top of the dial, allowing variations below and above that pressure on either side. The gage can be furnished illuminated or non-illuminated, and either single or double faced.

In addition to their standard line of temperature controlling instruments, C. J. Tagliabue Mfg. Co. showed a new type of fully compensated mercury-filled recording thermometer. This thermometer is designed so that tube lengths up to 200 ft. can be employed without sacrificing accuracy. Another new item in their exhibit that attracted the attention of engineers was Tag-Hespe glass for industrial thermometers. This glass is designed so that a red line forms the back wall of the bore, thus making the thermometers extremely easy to read even at considerable distances.

The American Schaeffer & Budenberg Corp. called particular attention to a new type of mercury-actuated temperature control. One of the features of this control is that it can be operated at temperatures from — 40 to + 100 deg. F.

Taylor Instrument Companies displayed their new type of distance reading recording thermometer. Changes in temperature at the point to be measured are transformed into electrical impulses which are sent by the long distance transmitting device through an electrical circuit to the recorder at any convenient point. Interest was also shown in the Tycos direct-reading superheat indicator, designed to give a direct-reading of superheat without using steam table. In this indicator an adjustable auxiliary scale besides the regular thermometer scale is set with its zero point on the steam pressure marked on a third scale. Then, opposite the regular temperature reading, the degree of superheat is read direct on the adjustable auxiliary scale.

Round and rectangular patterns of Weston electrical meters for all electrical measurements were attractively mounted on switchboard panels in the booth of Weston Electrical Instrument Co. An electrically operated speed indicator, which can be arranged for all types of rotating apparatus, was displayed.

hours at full load without necessity for replacement or repair of any of the parts. At 90 r.p.m. it developed 650 hp.

The Crankless Engine Co. of America presented a new type of solid injection Diesel engine, in which the reciprocating motion of the pistons, instead of being transmitted through cranks, is changed to rotating motion by

METERS, SUPERHEATERS, EVAPORATORS AND HEATERS, BLOWERS AND REGULATORS WERE SHOWN

Fig. 28. Multi whirl coolers, Reilly evaporators and heaters and the U-fin generator air cooler were pleasingly displayed by the Griscom-Russell Co. Fig. 29. Jenkins Bros. had on display a complete assortment of valves. Fig. 30. Mason Regulator Co. showed various working models of regulators and pump governors. Fig. 31. Wing turbine blowers, exhausters and the featherweight unit heater were emphasized by L. J. Wing Mfg. Co. Fig. 32. The new electric CO_2 recorder and the multiple draft indicator were shown by Republic Flow Meters Co. in addition to a new liquid level gage and various types of recording and indicating instruments. Fig. 33. A section of a superheater installed for the Illinois Power & Light Co. attracted interest at the booth of the Superheater Co. Fig. 34. Furnace Engineering Co. showed the Simplex unit pulverizer and the Simplex turbulent burner for pulverized coal.

Worthington Pump & Machinery Corp. called special attention to the parts of the single cylinder, double-acting, two-cycle oil engine, which was exhibited at its booth. This engine ran for 30 days and nights on a test under Government supervision, and had a total run of 1300

the pressure of a ball joint on a wobbling plate. A four-cylinder engine, designed for speeds up to 500 r.p.m. and rated at between 125 and 150 indicated hp., was on exhibition.

A combined pulverized coal and oil burner, provided

with a cycloidal case to whirl the coal and air entering the burner and shorten the flame, was exhibited by Peabody Engineering Co. A central control system allows a large number of these burners, installed in several boilers, to be controlled from a central point. The oil burner can be used either as an auxiliary for low loads when the coal is shut off, or as a torch to ignite the pulverized coal burner.

L. J. Wing Mfg. Co. exhibited a recent design of their unit heater, known as the Featherweight. The general mechanical construction of this heater has been improved to lessen the weight, but to keep the capacity the same as in previous units. Models of the Wing turbine blower were shown, among them being a 29½-in. blower, which is the largest size made by this company up to the present time.

Connery & Co., Inc., showed a typical section of their standard wagontop breeching, incorporating the new type of dust-proof ball bearings for dampers, removable damper section and airtight cleanout door.

Irving Iron Works had an attractive exhibit of Irving Subway open steel flooring. This exhibit consisted of a short walkway of Subway flooring, with stairways constructed of Irving Safstep leading up to it. This subway grating is designed for great strength, cleanliness and prevention of slipping. The non-slipping step, known as Safstep, is of the same grating construction, except that it is made in units of proper size to fit the framework of the stairway. The surface of this subway grating is designed to be cool, comfortable and safe at all times, since it has 80 per cent of open area for ventilation, drainage and lighting.

Vastine Sales Corp. exhibited various types of the Vastine furnace fire observers, mounted in a model furnace to show the wide angle of vision obtained and the method of allowing air to enter through passages in the framework, cooling the latter and preheating the former.

The Permutit Co. also exhibited a new type of oil filter and a new type of small quick-acting Zeolite softener, that was developed originally for domestic use, but can be applied in the small power plant.

Industrial plant engineers visiting the show were interested in the exhibits of gears, mechanical drives, bearings, lubricating systems and the like. One of the most interesting displays of this kind was an improved model of the stroboscopic tester for belt slip, used at the booth of F. L. Smidth & Co. to compare and measure the slip of open, long-center and Lenix drives. In the tester formerly used for this purpose, an ordinary incandescent lamp with a revolving slotted disc was used to illuminate the crosses on the pulleys. In the tester shown this year, a Neon tube actuated by a commutator furnishes the illumination, and on account of its instantaneous action, the relative motions of the pulley arms are shown much more clearly. In addition to the stroboscopic tester, a large model of an actual Lenix drive was shown in operation. This drive is a short-center belt drive, designed for comparatively low belt tension, and to eliminate noise and increase capacity.

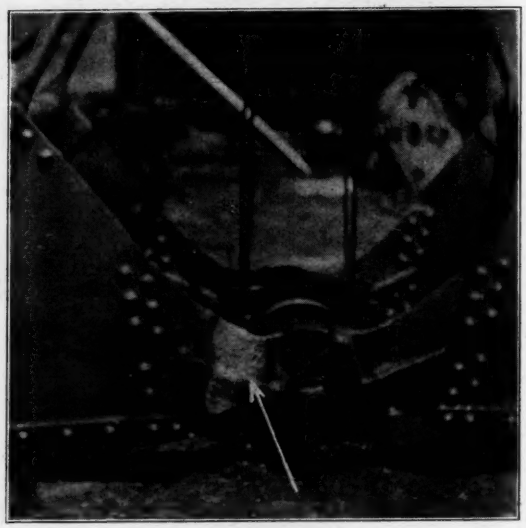
Another interesting feature of their exhibit was the new Allis-Chalmers Texrope Drive. In this drive a number of endless wedge-shaped bolts are used, fitted into V-shaped grooves in the pulleys. The drive is designed to eliminate slip and stretching, and to cause each belt to take its proportionate share of the load. It is particularly adapted to short center drives.

Keystone Lubricating Co. exhibited the Keystone Safety Lubricating System by a small model installation, showing the pressure cup, the grease pipe lines and the application of grease to bearings by this system. Several interesting photographs showed how the system has been applied to heavy machine tools, stoker drives and other mechanical equipment.

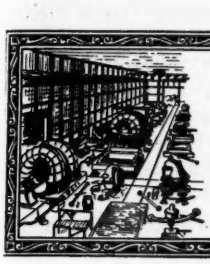
The center of interest at the booth of the Buffalo Forge Co. was probably a large metal-working machine, known as the Universal Iron Worker, which it was stated had found considerable application in the machine and repair shops of various power plants, and which is designed to cut, miter, punch and slit, all on the same machine, and is arranged so that two men can perform different operations of this kind at once.

Clam Shell Bucket Quickly Repaired by Welding

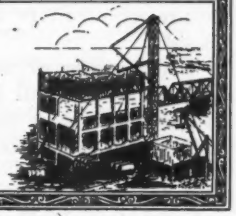
RIGHT IN THE middle of an important unloading job at a manufacturing plant, a clam shell bucket was put out of commission with a broken cast steel ear. This tied up the unloading crane and embarrassed the plant considerably, both because it held up the supply of needed material and because demurrage on freight cars was threatened. It would have taken several days to secure a new part for this bucket and then considerable time would have been required to install it. The plant was equipped with oxy-acetylene welding apparatus, so the welder was called upon to repair the piece. The casting was about ¾ in. thick, with a rib through the center, as shown. The parts were put in alinement and were prepared for welding by cutting out a V with the oxy-acetylene cutting blowpipe. After carefully cleaning away the slag, the break was then welded. The total time required for this work, including preparation and welding, was about 1½ hr. Within two hours from the time the break occurred, the crane was back at work.



CAST STEEL EAR WAS WELDED AT POINT INDICATED BY ARROW



POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS



Columbia Power Station Dedicated Dec. 10

DISTINGUISHED GUESTS from a dozen states, as well as thousands of visitors from Greater Cincinnati and Southern Ohio, participated in the dedication and public inspection of the new Columbia Power Station, at the confluence of the Ohio and Big Miami Rivers, west of Cincinnati, on Dec. 10-13, 1925. A feature of the formal program at Columbia Park at 1 o'clock on the afternoon of Dec. 10 was the christening of the plant by Virginia Junggren, daughter of Oscar Junggren, designer of the turbo-generators used in the new station. Miss Junggren took the throttle and turned on the steam for the first time. Charles P. Taft, representing the Board of Directors then threw the switch, releasing the energy of the station into the distribution lines of Columbia system. President Gossler made a brief dedication address.

At Cincinnati, the party was entertained in the evening at a banquet in the Sinton Hotel. Owen D. Young, chairman of the General Electric Co. Board of Directors and member of the Dawes Reparation Commission, was the principal speaker at the banquet. Others who talked were Philip G. Gossler, president of Columbia Gas & Electric Co., and W. W. Freeman, president of The Union Gas & Electric Co. Special arrangements were made to broadcast the banquet program through Stations WLW and WKRC. On Dec. 11-13, the three days following the formal inspection, the Columbia Power Station was thrown open to inspection by the general public.

Two turbo-generators operating at a pressure of 600 lb. per sq. in., with their boilers and auxiliary equipment, as described in detail in the Nov. 1 issue of Power Plant Engineering, comprise the initial installation at Columbia Power Station. The cost of this addition to the capacity of the C. G. & E. Co. system is approximately $20,000,000. The tandem type turbines are rated at 45,000 kw. each. The steam, heated to 725 deg., passes from the high pressure section at 425 deg.; it is then reheated to 725 deg. Pulverized coal is used for fuel. Steam is extracted from the turbine after partial expansion for heating feed water on the regenerative cycle; and the hot flue gases, before going up the stack, preheats the air for combustion. While the improvements mentioned have been utilized by other generating plants, the Columbia Power Station will be the first to combine all of them. The station was designed by Sargent & Lundy, Engineers, Chicago, Ill., in co-operation with C. W. DeForest, vice-president of the Columbia Power Co.

Columbia Power Station is so designed that, as demands require, new units will be added to the plant until it has been expanded to a maximum of eight turbines. Construction of the station was started February 14, 1924. The plant is located at the junction of the Ohio and Big Miami Rivers, in a section not previously settled. Now, however, a nucleus of a village has grown up, with 33 homes and a large clubhouse. The homes in this new village, known as Columbia Park, afford the greatest conveniences and comforts to the company's employes and their families at the least expense.

Chicago Power Show Chooses Slogan

DURING THE month of November the Midwestern Engineering Exposition, otherwise known as the Chicago Power Show, offered a $100 prize for the best slogan accompanied by the best explanatory letter suitable for use in connection with the Exposition to be held in Chicago, January 26 to 30, inclusive, 1926.

While the contest was on for but a limited time, nevertheless several hundred slogans were received, coming from all parts of the country and even as far as England and South America. The interest shown by engineers and others in offering a suitable slogan for the purpose of advertising a power exposition is manifest.

Under the requirements set forth in the contest, it was apparent that the winning slogan must be short and yet tell a complete story. It must also typify in some way the great field of usefulness for power and bring a thrill to every engineer who hears it spoken or sees it in print. With Chicago as the center of the greatest power pool in the world, it was apparent that the interest in this power exposition would extend throughout the entire country.

With the above as a background, the Midwestern Engineering Exposition is pleased to announce William W. Hatton, of 120 Broadway, New York, as winner of the contest with the following slogan:

Power Controls Man's Progress

Mr. Hatton's letter accompanying this slogan has merit and brings out the thought in connection with power activities which must be in the mind of every power man. Mr. Hatton says:

"Since man fashioned the first crude tools from trees and rocks, his progress has been ever cumulative. His use of tools, and their refinement power, has marked the several steps of progress in civilization. His utilization of the water-driven wheel, the stored energy of combustion, the power of controlled steam and gas, all led to the innumerable uses of electricity when that marvel was brought within his ken.

"Today, vast as has been his accomplishment in the physical realm, let him in humility study the giant steps of his progress, and admit the possibility of even more amazing advance in applying the forces of Nature; let him use his accumulated knowledge for devising further aids

to civilization, to the end that mankind, having lifted to some extent the curse of Adam, may have more leisure, acquire more culture and greater opportunity to develop its soul."

Several other slogans were deserving of special merit and the authors will be properly recognized by suitable awards made during the week of the Chicago Power Show at the American Exposition Palace.

Collection of Statistics Will Aid Waste Elimination

NEED OF SYSTEMATIC collection of statistics as a first step in the elimination of immense wastes in distribution due to wide market fluctuations was pointed out in a report to be submitted by a committee of government officials and business executives, of which Owen D. Young is chairman, to the National Distribution Conference at its meeting in Washington on Dec. 15, under the auspices of the Chamber of Commerce of the United States. The report represents the first concerted move on the part of American business men to avert the disastrous booms and slumps which result in waste and extravangance and subsequent stagnation and unemployment.

Secretary Hoover, who selected the members of the committee at the request of the Conference, said, in outlining its purpose, "We are almost wholly lacking in the basic data as to distribution. It is my hope that this Committee may sponsor and direct a broad inquiry into the business statistics now available and into the needs of the various branches of industry in the collection of additional figures and make recommendations as to the best methods, public and private, of obtaining a more accurate knowledge of the marketing areas, so as to approach more intelligently a discussion of wastes in distribution."

In its report the Committee says: "We conceive that our present statistical situation follows not from the want of ability and effort in the various collecting and interpreting agencies, whether private or public, but rather that waste flows from disorder, and that, if we may order this effort through a common understanding of our general needs, we shall have arrived at an ideal of attainment in obtaining statistics of business and industry.

"Business statistics are the only effective guide to balanced production and distribution. They are the only means for co-ordinating demand with production and uninterrupted employment. Their results would be felt by every human being in the country from the individual owner of the largest factory down to the humblest workman of the field."

New Construction by Byllesby Utilities

COMPLETION of a new construction project involving the expenditure of approximately a million dollars and plans for two other projects, costing a total of approximately $2,750,000 were announced recently by Byllesby Engineering and Management Corp. The Flambeau reservoir, which will flood an area of approximately 20,000 acres and store some 6,000,000 cu. ft. of water, is the project just finished. The two new projects will provide increased electric generating capacity for San Diego Consolidated Gas & Electric Co. and Oklahoma Gas & Electric Co.

The dam forming the Flambeau reservoir is on the upper Flambeau River in Wisconsin. It was built by the Chippewa and Flambeau Improvement Co. and engineering and inspection service was by the Byllesby Engineering and Management Corp. The Flambeau reservoir will be operated by the Northern States Power Co. of Wisconsin.

New construction at San Diego will consist of a new 20,000-hp. turbine at Station B, one additional boiler of 1100 hp., and new condensing water tunnels extending about 1300 ft. from the generating plant to the bay. Construction of the tunnels is now under way and plans for installation of the station equipment, which is being purchased, are in progress.

A new 27,000-hp. generating unit, with the necessary condensing equipment and auxiliaries will be installed at the Horseshoe Lake Plant of Oklahoma Gas & Electric Co., near Harrah, 23 mi. east of Oklahoma City, together with a 1000-hp. boiler designed for burning powdered coal, using the new unit pulverizing system.

An order for eight 13,500-hp. water wheels, costing, with incidental equipment, more than $550,000, has been placed by the Louisville Hydro-Electric Co., a subsidiary of the Louisville Gas & Electric Co., with Allis-Chalmers Mfg. Co. This is part of the equipment for the new Falls of the Ohio River electric station being built on the Ohio River at Louisville.

Edison Medal Awarded to Professor Harris J. Ryan

THE EDISON MEDAL for the year 1925 has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to Harris J. Ryan of Stanford University, California, "for his contributions to the science and the art of high-tension transmission of power."

The Edison Medal was founded by the Edison Medal Association, composed of associates and friends of Thomas A. Edison, and is awarded annually by a committee consisting of 24 members of the American Institute of Electrical Engineers for "meritorious achievement in electrical science, electrical engineering, or the electrical arts."

Harris J. Ryan, Professor of Electrical Engineering, Stanford University, California, was born in Powells Valley, Pa., January 8, 1866. He studied at Baltimore City College, Lebannon Valley, and received the degree of M. E. in Electrical Engineering from Cornell in 1887. In 1888 he became a member of the Western Engineering Co. at Lincoln, Nebraska, and in 1889 Instructor in charge of the electrical machinery laboratory at Cornell. From 1890 to 1895 he served as Assistant Professor of electrical engineering in provisional charge of the department and from 1895 to 1905 was Professor in charge of the department of electrical engineering. In 1905 he accepted the same position at Stanford University which he holds today. In 1909 Profesor Ryan became consulting engineer for the Los Angeles Aqueduct Power Development. During the war as a member of the Pacific Coast Section of the Submarine Group of the National Research Council he carried on valuable work and in 1918 and 1919 was in charge for the Research Council Supersonics Laboratory at Pasadena.

During Professor Ryan's twenty years at Stanford, he has been a pioneering leader in high-voltage transmission, upon the development of which largely depends the future growth of the Pacific Coast region. About three years ago the first 220,000-v. power lines were successfully put into commission by California companies, and Professor Ryan cooperated with the engineers in finding ways to cope with the insulator problems encountered, and it is on the solution of similar problems that his genius in the research field is expected to continue an outstanding advantage to science.

A. I. E. E. Nominates for Office

THE NATIONAL NOMINATING COMMITTEE of the American Institute of Electrical Engineers, consisting of 15 members from various parts of the country, has nominated the following official ticket of candidates for the offices falling vacant August 1, 1926. For president: Cummings C. Chesney, manager and chief engineer, General Electric Co., Pittsfield, Mass. For vice-presidents: Northwestern district—H. M. Hobart, consulting engineer, General Electric Co., Schenectady, N. Y.; New York City district—George L. Knight, mechanical engineer, Brooklyn Edison Co., Brooklyn, N. Y.; Great Lakes district—B. G. Jamieson, engineer of inside plant, Commonwealth Edison Co., Chicago, Ill.; Southwest district—A. E. Bettis, vice-president, Kansas City Power & Light Co., Kansas City, Mo.; Northwest district—H. H. Schoolfield, chief engineer, Pacific Power & Light Co., Portland, Ore. For managers: F. J. Chesterman, chief engineer, Bell Telephone Co. of Penn., Philadelphia, Pa.; H. C. Don Carlos, operating engineer, Hydro-Electric Power Commission of Ontario, Toronto, Ont.; I. E. Moultrop, asst. supt., construction bureau, Edison Electric Illuminating Co. of Boston, Mass. For treasurer George A. Hamilton, electrical engineer (retired), Elizabeth, N. J.

These official candidates, together with any independent nominees that may be proposed later in the manner specified by the constitution and by-laws, will be voted upon by the membership at the coming election in the spring of 1926.

Wind Pressure on Model of Building Determined by Bureau of Standards

AVERAGE WIND PRESSURE on a tall building when the wind is blowing at 76 mi. per hr. (100 mi. per hr., as shown by a Weather Bureau, Robinson type anemometer) is about 22 lb. per sq. ft. according to results obtained by the Bureau of Standards, Department of Commerce. The value which is commonly used is 30 lb. per sq. ft. This would correspond to a true wind speed of about 88.5 mi. per hr. (118 mi. per hr. indicated speed). Gusts of this speed have been observed in only a few cities, such as New York, and St. Paul.

These results were obtained by measuring the force of the wind on a model of a tall building mounted in the large outdoor wind tunnel of the Bureau. By means of small openings in the face and top of the model which were connected to a pressure gage, the pressures produced by the wind at various parts of the structure were measured. These measurements were made at 70 places on the face of the model and at 49 places on the top, with the wind coming from 13 directions, varying from directly against one face to directly against the opposite face. The pressures obtained were then multiplied by the appropriated areas to give the total force on the model under the different conditions. The forces tending to overturn and to twist the model were also computed.

This work was undertaken because of the many inquiries received by the Bureau concerning wind pressures on buildings. The same experimental methods were employed which have been found so useful in the investigation of air forces on airplanes.

The Bureau has determined the actual pressure corresponding to a given wind velocity. There still remains the problem of determining what wind velocity to use in designing a structure. Obviously, a higher velocity ought to be assumed in designing a building facing the lake front in Chicago than for a building in the downtown section of Washington.

Babcock & Wilcox Co. Buys Fuller-Lehigh Co. and Bailey Meter Co.

THE BABCOCK & WILCOX CO. announces that it has purchased the Fuller-Lehigh Co. and its subsidiaries, manufacturers of pulverized fuel and cement mill equipment; also that it has purchased the Bailey Meter Co., manufacturers of meters and recorders, combustion control equipment, pulverized fuel feeders, and water cooled furnace walls. The Fuller-Lehigh Co. and the Bailey Meter Co. will be operated with the same organizations as heretofore, with the exception that Col. J. W. Fuller will become Chairman of the Board of the Fuller-Lehigh Co., E. G. Bailey will become President, and A. E. Douglass of Fuller-Lehigh Co. will become Vice-President in charge of Sales. Mr. Bailey will continue to act as President of the Bailey Meter Co., and R. S. Coffin will continue as Vice-President and General Manager.

By the acquisition of these companies The Babcock & Wilcox Co. will be able to offer boilers, superheaters, economizers, air heaters, chain grate stokers, oil burners, pulverized fuel equipment, water cooled furnace walls, meters, and combustion control equipment; all in any combination that may be required to supply complete steam generating units.

Work Started on Androscoggin River

THE CENTRAL MAINE POWER CO. has started work on the Gulf Island hydroelectric development in the Androscoggin River a short distance above Lewiston, Me. This development will cost approximately $5,000,000 to complete and with the interconnections made by the electric company, will supply power and light to Lewiston, Auburn and more than a score of other cities. More than 400 men are at work on the site.

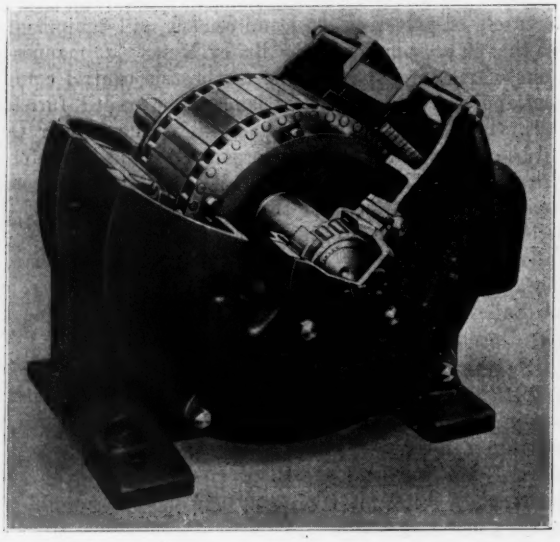
The dam will be 2700 ft. long and 50 ft. high and will hold back a billion cubic feet of water; the lake which it will create will extend back a distance of 9 mi. and its maximum width will be 1 mi. Three 9000-hp. units will be installed with provision for the addition of a fourth unit. The dam is to be completed during 1927.

Work on the project will be carried forward under the direction of the New England Public Service Co., of which Walter S. Wyman of Augusta, Me., is president. This company is a subsidiary of the Insull interests. The same

interests have also just awarded contracts for the first of five hydroelectric plants to be built in the vicinity of Hillsboro, N. H. The initial unit, to be known as the Jackman plant, will cost approximately $750,000 and the ultimate five units will involve over $3,000,000 expenditure and will take about 5 yr. to complete. The Realty Development Corporation, a subsidiary of the National Light, Heat and Power Co. has been organized to develop the new plants on the Contoocook River and the output of the five units will be approximately 43,000,000 kw-hr. per annum. The Jackman unit will supplant the Garvin Falls station of the Manchester Traction, Light & Power Co. of Manchester, N. H., during periods of low water at the Garvin Falls plant.

Allis-Chalmers Develops New Roller Bearing Motor

AFTER CONSIDERABLE experimentation the Allis-Chalmers Manufacturing Co. of Milwaukee, Wis., has recently placed on the market a complete line of 25 and 60-cycle squirrel cage and slip ring induction motors equipped with Timken tapered roller bearings. These motors are particularly suited to heavy service and will operate satisfactorily at the high speeds found in the general purpose induction motor. Because of the rolling action of the bearings there is practically no wear, so the factory adjusted air gap is maintained indefinitely, eliminating any possibility of the rotor striking the stator.



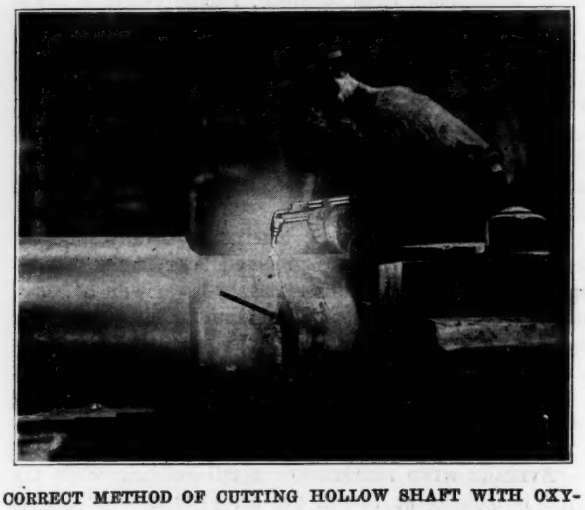
SECTIONALIZED VIEW TYPE A R ROLLER BEARING MOTOR

Lubrication is greatly simplified, as grease requiring very infrequent attention on the part of the operator is used. This is an important point, because it has been found from experience that a great many motor troubles can be traced to improper lubrication. The bearings have grease tight enclosures effectively excluding dirt or abrasive matter that might cause undue wear of the bearings. The mounting of the bearings is exceedingly simple, being only a light press fit for both the cone and cup, and not requiring the use of a lock nut or other means of holding the races in place. This also facilitates the removal of the bearings whenever necessary.

In addition to the bearings, special attention has been given to many other features of design of this line of motors. This motor has to meet the many severe conditions found in its application to the various types of machinery manufactured by the company. The frame is made of steel with feet cast integral, to withstand shocks encountered in use with the crushers, grinders and other machinery. In applying the motors to the centrifugal pumps, very often severe conditions of moisture are met so that the coils are thoroughly insulated and baked in a water-proof varnish. In sawmills, flour mills and cement mills, motors must operate in dusty and dirty places, so that the scheme of ventilation must successfully meet these conditions. The openings in the housings and frames for ventilation are so placed in vertical planes that falling objects cannot enter the motor. The roller bearing motor is particularly adapted to many applications because the overall length is considerably less than for a sleeve bearing machine. This motor can now be obtained in all ratings, 25 to 60-cycle, 200 hp. and smaller.

Simple Change Improves Oxy-Acetylene Cutting Method

AT A Mississippi Valley power plant, in which new turbines were being installed and some of the former equipment being removed, it was decided to purchase oxy-acetylene cutting equipment to use in cutting shafts and wrecking other old equipment and to instruct one of the plant workmen in its use. This would eliminate the need for having an outside company do the work. Accordingly, the cutting equipment was obtained, says Oxy-Acetylene Tips, and the operator of it learned rapidly how to handle the blowpipe and soon became proficient in ordinary work.



CORRECT METHOD OF CUTTING HOLLOW SHAFT WITH OXY-ACETYLENE BLOWPIPE. ARROW SHOWS WIDE KERF OF ORIGINAL CUT MADE INCORRECTLY

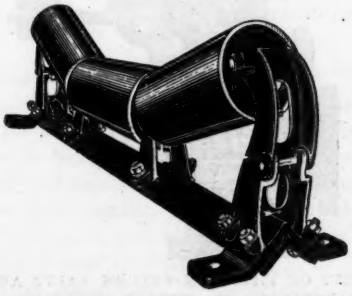
In the course of the demolition work, however, it became necessary to cut off a hollow shaft 30 in. in diameter with walls 9 in. thick. On this work the operator did not progress so well. He stood on the floor beside the shaft and, in attempting to make a cut, succeeded only in slotting out a wide section in the side of the shaft without progressing very far through it. The result of his attempt is indicated by the arrow in the accompanying photograph.

Upon being called into consultation, an oxy-acetylene service engineer immediately suggested that the operator sit on top of the shaft and cut down, as shown in the photograph, while the shaft was rotated slowly so that the cutting could always be done toward the center. When this was done, a narrow kerf resulted, as can be seen, and the work went forward rapidly. In addition to speeding up the work, the second method resulted in using a much smaller amount of both oxygen and acetylene than would have been necessary otherwise. These results indicate the course that should be followed by users of oxy-acetylene welding and cutting equipment when similar difficulties arise in using this process.

Ball Bearing Conveyor Carrier

POWER is required to convey coal but for economy this should be as little as is positively necessary to do the work. This principle has been recognized by the Stephens-Adamson Mfg. Co. of Aurora, Ill., in the design of the new Sacon belt conveyor carrier which has incorporated in it features intended to reduce friction to a minimum.

This new carrier is of the three-pulley type and is equipped with high grade ball bearings that carry the roll



SACON BELT CONVEYOR CARRIER IS EQUIPPED WITH BALL BEARINGS FITTED FOR PRESSURE LUBRICATION

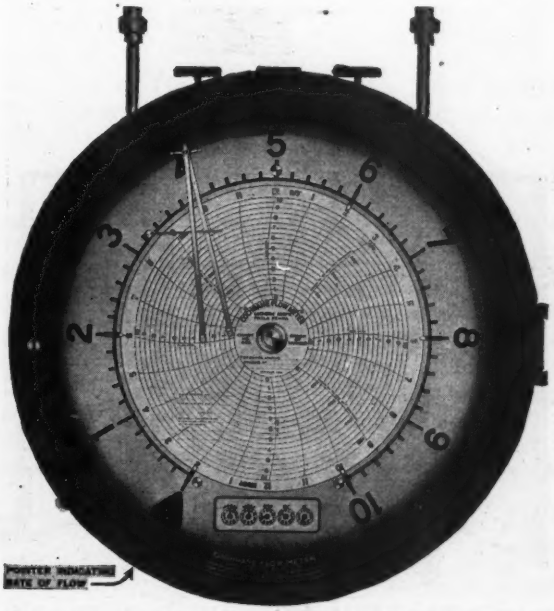
shafts. All bearings are fitted for high pressure lubrication and the combination results in a conveyor which offers comparatively little frictional resistance. The malleable iron stands are mounted on the rigid horizontal angle tie and the moving parts are easily removed for inspection.

Recording Gages and Flow Meter Combined

TO DETERMINE correctly the weight of water, gas or vapor from the record of a pipe flow meter, it is necessary to know the density of the fluid passing through the orifice or other metering element. This implies a record of pressure or temperature, or of both, in order to be able to determine the density of the fluid. Continuous records of pressure and temperature are also useful for other purposes, as for determining the efficiency of boilers, economizers or heaters or the superheat in steam supplied to turbines or other prime-movers.

The Cochrane Flow Meter shown herewith is designed to make these additional records of temperature and pressure upon the flow meter chart itself. The pens of the temperature and pressure units are actuated by helical Bourdon tubes, calibrated to record pressure or temperature accurately over specific ranges. The pressure unit is provided with a half-inch pipe connection at the meter, while the thermometer unit is supplied complete with capillary tubing, bulb and separable socket.

On this instrument the pen or pens which record temperature or pressure rotate about the same axis as the flow pen and have a radio movement of 4 in. on the chart. In order that the several pens may clear one another, they are spaced apart by distance representing ten minutes of time. The pens are provided with micrometer adjustments and with a pen-lifting device which holds the pens clear of the chart while the latter are being changed. The recording thermometer is of the type which utilizes the expansion of an inert gas contained in a bulb inserted where the temperature is to be measured, different styles of bulbs being supplied for different situations. The type of bulb used for measuring flue gas, for example, is sensi-



THIS METER WILL INDICATE AND INTEGRATE FLOW AT THE SAME TIME RECORDING FLOW, TEMPERATURE AND PRESSURE

tive over a length of 24 in. from the tip and the sensitive part should be located in such a position that it will be exposed to average temperatures. The bulb used for measuring steam or water is supplied with a separable socket of bronze for saturated steam and of steel for superheated steam.

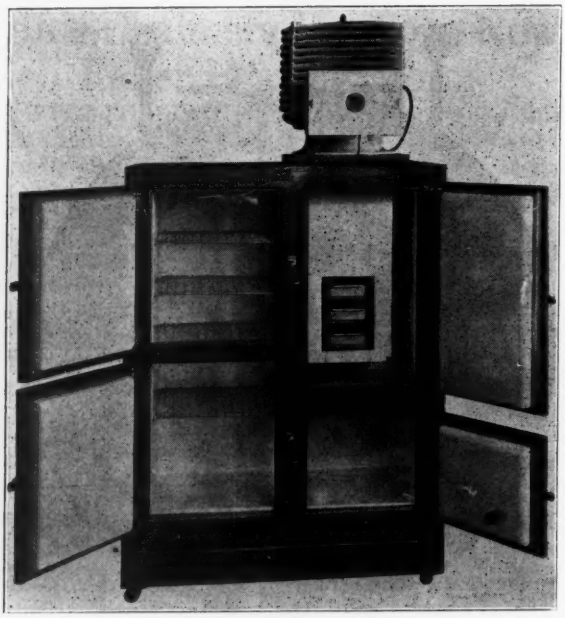
Thermometer and pressure scales are uniform, like the scale of the flow meter chart; that is, the spacings between the lines are the same for high values as for low values. Deflection in proportion to flow rather than in proportion to differential pressure is secured in this flow meter by the use of a cam fastened to the tilting manometer which presses against a weighted metallic ribbon and is so shaped that the force exerted by the ribbon increased with the deflection. The chart upon which temperature, pressure and flow are recorded is driven by a powerful clock, which also actuates an integrator without imposing any resistance to the deflection of the manometer balance.

This new combination meter is being placed on the market by the Cochrane Corp., Philadelphia, Pa.

FUEL OIL in storage should be heated as little as possible, because a much larger percentage of the light oils are driven off by the application of heat than is generally supposed.

New Electric Refrigerator Has Enclosed Mechanism

AN ELECTRIC refrigerator in which the mechanism is totally enclosed, which is practically silent in operation and which requires no attention for lubrication has been announced by the General Electric Co. This machine is a departure from conventional lines in that all the refrigerating mechanism is contained in one unit, set into the brine tank through the top of the cabinet. The motor, compressor and all moving parts are hermetically sealed in a case containing the refrigerant and lubricating oil. The motor and compressor are mounted vertically on the same shaft and cylinder pressures are equalized by a valve device, allowing the motor to start under no load. Installation includes only setting the cabinet in place, placing the brine tank in the box and filling with brine, setting the unit on the cabinet and plugging in the motor lead.



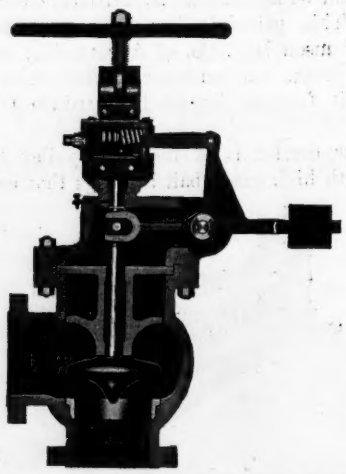
THIS NEW REFRIGERATOR UNIT, HERMETICALLY SEALED IN CASE, USES SULPHUR DIOXIDE AS REFRIGERANT

This unit is designed for use with any one of several sizes of boxes, of one of two finishes and lined with white vitreous porcelain fused on steel. Corkboard insulation is used. Easy access for cleaning is allowed into the food compartment. Ice trays for freezing cubes are also included. The only maintenance required is the shutting down of the machines overnight once or twice a month to allow the accumulated frost on the brine tank to melt. As this melting keeps the box cool, refrigeration is not sacrificed. The refrigerator will be sold only complete with cabinet and unit.

The principle of operation is the evaporation of the liquid refrigerant (sulphur dioxide) in the evaporator coils submerged in brine. Complete thermostatic and electrical control are provided. The automatic control is so adjusted that the temperature of the brine tank is maintained between 16 deg. and 24 deg. F. Daily operation covers a period of approximately 10 hr. Investigations show that a temperature range of from 40 deg. to 50 deg. F., depending on room temperature, is best adapted for food preservation, and the area of the brine tank in this refrigerator is such as to maintain that temperature range in the food compartment.

Non-Return Valve for High Pressure and Superheat

DESIGNED FOR high pressures and high superheat and recommended for pipe lines in which high velocities of steam are employed, the new Class XD, stream line flow, non-return valve has recently been put on the market by the Elliott Co. This valve is built for working pressures up to 400 lb. and total temperatures up to 800 deg. F. It has been designed to give stream line flow; there is no supporting web in the seat and the passages between seat and disc, as shown in the illustration, form a venturi throat. Seat and disc are constructed to make line contact, bearing surfaces are of unlike metals and large factors of safety have been employed. The minimum area through the valve is 1.1 times the pipe area.



DISC AND SEAT OF THIS NON-RETURN VALVE ARE DESIGNED FOR STREAM LINE FLOW

Built in angle and straight way patterns in sizes from 5 to 12 in., the Class XD valve has a cast steel body. All moving parts are supported on one large center bearing; the dashpot is of the external plunger type and can be inspected and oiled with the valve on the line. The weight of the moving parts is partly supported by the outside balancing weight, the position of the balancing lever also indicating the location of the disc with respect to the seat. The Class XD valve is custom built with flanges according to the customers' requirements.

AT PLANT No. 3 of the Kalamazoo Paper Co., Kalamazoo, Mich., work is going forward rapidly on an extensive expansion program. A 168-in. Rice, Barton & Fales paper machine is being installed and the power plant is being enlarged to contain three stoker-fired vertical tubular boilers of 500 hp. each with economizers and superheaters, a 2500-kw. steam turbine with condenser and an extensive motor and switchboard installation. A. M. Adams, Supt. of Power, and W. H. Scott, Master Mechanic, of the Kalamazoo Paper Co., designed this improvement and are superintending its construction.

News Notes

AT A MEETING OF the Council of the American Society of Mechanical Engineers, held in New York on November 30, 1925, John A. Stevens, former chairman of the boiler code committee of the A.S.M.E., was honored by being made honorary chairman of that committee. An engraved testimonial presented to him on this occasion, reads as follows: "The Council of the American Society of Mechanical Engineers, at the unanimous request of the Boiler Code Committee, and in recognition of this fourteen years of service as its leader and chairman, has appointed John A. Stevens honorary chairman of the Boiler Code Committee."

DR. PARKE REXFORD KOBEL will be installed as president of Polytechnic Institute of Brooklyn, N. Y., on the evening of Jan. 13. He comes to this position from the presidency of the Municipal University of Akron, O., where he has been located for the past 12 yr. The inaugural exercises are in charge of a general committee, M. S. Sloan, president of the Brooklyn Edison Co., chairman; James S. Davis, E. P. Goodrich and Joseph P. Carlin, acting with representatives of the faculty. The principal address will be by Dr. Charles A. Richmond, president of Union College and presentation of the seal and keys by Charles E. Potts, chairman of Board of Trustees of the Institute.

ENGINEERS of the Bureau of Chemistry, United States Department of Agriculture, have recently developed new apparatus for exploding industrial dust by electric sparks. The bureau is being called upon continually for demonstrations of dust explosions before national organizations, conventions, and similar meetings, and also by grain handling companies and similar industries to test the various kinds of dust produced during grain handling and manufacturing operations. In the original apparatus designed by the bureau, the ignition was produced by an open flame and served as the means of bringing the dust explosion hazard to the attention of workmen and operators in industrial plants. It was difficult, however, in the use of the open flame to control the explosions in an effective way. In addition to the demonstration feature, the new equipment affords a possibility of testing all types of industrial plant dusts to determine the possibility of ignition by electric sparks.

J. H. SUTHERLAND, formerly with the Ford Motor Co. of Canada, has just been appointed Detroit district sales representative by the Pittsburgh Valve Foundry and Construction Co. of Pittsburgh, Penna., succeeding G. Howard Boddy.

KEENE GAS & ELECTRIC Co., Keene, N. H., is to be sold Jan. 1, if the necessary 85 per cent approval to the plan is secured from the stockholders at the annual meeting to be held on that date. The transaction involves about $1,200,000. It is understood that the Insull interests and the Middle West Utilities Co. of Chicago are interested in the purchase.

W. J. NUGENT, vice-president and general manager of the Nugent Steel Castings Company, Chicago, has been elected president to succeed Charles Piez. Prentiss Coonley has been elected Vice-President and C. A. MacDonald, Secretary, has been elected to fill a vacancy on the Board of Directors. Mr. Nugent has been associated with the company since 1918, when the present plant was erected. From 1918 to 1921 he served as vice-president and in 1921 became general manager as well. It is announced that there will be no change in policy as a result of the recent changes in officials.

GREENE, TWEED & Co., 109 Duane St., New York City, has recently reorganized its factory at Newark, N. J., for the manufacture of Rochester automatic lubricators and to give it complete equipment for the manufacture of cast and wrought goods in brass, bronze or white metal.

HERBERT E. SMITH, general sales manager of the United States Rubber Co., has been elected a second vice-president of the company in general charge of sales activities of all commodities except tires, succeeding George H. Mayo, retired.

C. F. PHILLIPS has been appointed representative in charge of the Wilkes-Barre office of the Allis-Chalmers Mfg. Co. Mr. Phillips, who was formerly connected with the Philadelphia office of the Company, succeeds Guy V. Woody.

JOHN F. BOUTELLE passed away, at his home near Atlanta, Georgia, on December 5, after an illness of several months. He was 55 years old and had represented the Dearborn Chemical Co., Stationary Department, in Southern territory since 1908.

THE SUPERHEATER Co., of New York and Chicago, announces the appointment of R. L. Ehmann as district manager of its Industrial Department, with office at 923 Union Trust Bldg., Pittsburgh, Pa. The former manager of the Pittsburgh office, John R. LeVally, has been assigned to special duties with the company and may be reached through the New York office.

WILSON-SNYDER MANUFACTURING Co., Pittsburgh, Pa., has been awarded a contract for constructing 24 pipe line pumping engines. These pumping engines will be installed in 8 pumping stations, which the Crusader Pipe Line Co. of Arkansas will build in connection with their new oil pipe line now being laid from the Smackover field near Eldorado, Ark., to the Mississippi River, near Munroe, La., a distance of approximately 150 mi.

FIRE, following an explosion of a voltage regulator in a distribution substation of the Bureau of Power & Light of Los Angeles, California, Tuesday, Nov. 24, completely destroyed the entire low-tension side of the substation. The old style voltage regulator with a cast-iron shell blew up as a result of a short circuit which put a tremendous pressure upon it. The explosion set fire to the interior of the substation and the low tension room was completely gutted. Operator E. L. Goodwin was at the other end of the substation at the time of the explosion and escaped injury. The station was put back into operation with 6 hr. Loss has been estimated to be between $25,000 and $35,000,

PRELIMINARY PLANS are being drawn for the construction of a new laboratory building at the School of Engineering, Princeton University, Princeton, N. J., to cost close to $500,000, with equipment. The new structure will be provided with laboratories and facilities for all phases of work. The ground floor will have a hydraulic laboratory, equipped with pumps, turbine apparatus, etc., for testing and research; another laboratory will be devoted to steam engineering, with equipment to include steam engine, gas engine, air compressors, refrigerating apparatus,

etc., as well as facilities for steam turbine and boiler work; the electrical laboratory will include generators, motors, switching apparatus, switchboards, etc. Large lecture rooms will be arranged. The new building will be constructed and equipped under the direction of Professor Arthur M. Greene, Jr., dean of the School of Engineering at the University.

THE TEXAS POWER & LIGHT CO., Dallas Texas, has active construction in progress on a new steam-operated electric generating plant on site about 1 mi. from Trinidad, Tex. The initial plant unit of 20,000 kw. is expected to be ready for service during the spring of next year, while the second unit, of like rating, will be completed in the fall. It is proposed to build additional units, as required, with ultimate capacity of 160,000 kw. The new station will be unique in the fact that pulverized lignite will be used entirely for fuel. The new power plant is being built by the Texas Construction Co., an affiliated organization, while H. F. Lincoln is construction manager in charge.

DODGE BROTHERS, INC., Detroit automobile manufacturers, are improving their power plant and increasing its capacity by installing new Taylor underfeed stokers under four boilers of 1287 hp. each. The air required to support combustion will be heated before it is supplied to the furnaces fired by two of these stokers, as is done in the most up-to-date central stations of the electrical industry and a few recently constructed power plants of industrial concerns. It is planned to operate these boilers around 225 per cent of their rated capacity, but when necessary to take care of peak loads the stokers can push the boilers to much higher ratings.

WILLIAM C. BLISS, chairman of the Public Utilities Commission of Rhode Island, has been appointed by Gov. Pothier as a member of the joint commission to study the question of regulation and interstate transmission of electricity for light, heat and power. Mr. Bliss will represent the state of Rhode Island on that board. The board is composed of representatives from New York, New Jersey and Pennsylvania and each adjoining state has been invited to name a representative to take part in the study.

THE CENTRAL MAINE POWER CO. is having preliminary plans prepared for a power house at Lewiston, Me. J. H. Stevens of Portland, Me., is preparing the plans for the building and F. W. Mason of Waterville is the engineer in charge. The new power unit will cost about $75,000.

Book Reviews

POWER PLANT LUBRICATION, by W. F. Osborne; cloth, 6 by 8 in., 275 pages, 84 illustrations; first edition, New York, 1925; price $3.00 net.

It has been the author's purpose, in writing on the lubrication of power plant machinery, to show the application of the theories and principles of lubrication, which have been worked out by many engineers and discussed in detail in other works. The discussion is further limited to applications of lubricants obtainable in this country.

After a brief treatment, in Part I, of the physical and chemical properties of lubricating oils and grease, the author shows how the fundamental principles of lubrication are applied in the power plant. Lubrication of steam turbines and engines, air compressors, refrigerating machinery and internal combustion engines is described, together with various lubricating systems and devices used. A chapter on buying lubricants is included and the book concludes with a discussion of standard methods of testing, referring particularly to A. S. T. M. and U. S. Government tests.

TRANSACTIONS OF THE First World Power Conference at London, England. Published by a committee of the Conference. Distributed by the American Committee, O. C. Merrill, General Chairman, Federal Power Commission, Washington, D. C. 4 vols., 6 by 9 in. Bound in green buckram cloth. Vol. I, 1500 pp.; Vol. II, 1600 pp.; Vol. III, 1500 pp.; Vol. IV, 1800 pp.

Review of such a monumental work is almost an impossibility and the best that can be done is to give some slight idea of the wealth of information to be found in these books.

Volume I is chiefly devoted to a summary and review of the power resources of the world, covering Africa, the Americas, Asia, Australia, the British Empire and the European countries, and dealing with fuels, water powers, winds, waves and tides. The papers presented give, in detail, the power available, developments made and under way and the general plan and detail methods used in various countries for generating and distributing power and for getting the best results from fuels and water powers. It is the first time that a comprehensive view has been presented of the world's power and the way it is being developed and used.

Volume II gives details of practice in steam plant and hydraulic plant engineering. Some of the major topics, on many of which a number of papers are presented, are: Water Power Development; Storage and Regulation of Stream Flow; Water Turbine Design; Steam Generation; Preparation of Fuels, Including Low-Temperature Carbonization and Pulverized Fuels; Recovery of Waste Heat; Use of High-Pressure Steam. This volume gives a picture of power plant practice of the world and the variations in different countries as of 1923-24.

Volume III deals largely with electrical equipment and methods for generation and distribution and with internal combustion engines. Generators, motors, switchgear, line construction, high-voltage transmission by overhead lines and by cables are some of the subjects treated, the practice for all countries being presented by engineers from those countries. One interesting paper describes the Natural Steam Power Plant at Larderello, Italy, where steam at 30 lb. is taken from wells and utilized in low-pressure heat exchangers and turbines.

Under combustion engines, large gas engines, Diesel engines, the status of gas engine development and use as well as the use of gas for power, industrial work and illumination are the subjects of several papers. The volume gives an interesting comparison of transmission practice in the various countries and the way that systems have been adapted to the conditions to be met.

Standardization and research and methods of illumination are other subjects treated in this volume.

Volume IV deals chiefly with the use of power in industries and for domestic purposes. Agriculture and electricity, use of electricity in chemical and metallurgical plants, mining, lumber, electric railways, ship propulsion

by electricity, by combustion engines and by steam power are some of the more important topics. Engineering and commercial education are given considerable attention, also the economic aspects of power resources and the effects of power use on finance, labor, social conditions and industrial progress.

It is safe to say that these transactions will stand for many years as the authoritative reference on power resources, development and methods of utilization, for the ablest engineers and economists of all countries contributed the papers which are here brought together.

Following each paper is the substance of the discussions which were presented at the various meetings of the Conference so that the four big volumes give a complete history of the technical side of the First World Power Conference. It will be found an invaluable reference work for libraries, colleges, engineering organizations and the practicing engineer.

An index volume has been prepared of 600 pages and 40,000 references, bound uniform with the transactions, and giving exhaustive reference to any one subject in all four volumes. Prices for the Transactions and the index can be had from O. C. Merrill, Federal Power Commission, Washington, D. C.

BULLETIN No. 67 of the Engineering Experiment Station of the University of Illinois, entitled "Reinforced Concrete Wall and Column Footings," by A. N. Talbot, originally issued in 1913, and which has been out of print for a number of years, has just been reprinted on account of the continued demand for it. This bulletin contains a description of tests on a number of different types of reinforced concrete wall and column footings. A limited number of copies are now available at the price of sixty-five cents each and may be obtained by addressing the Engineering Experiment Station, Urbana, Illinois.

"PATENTS and How to Obtain Them," is a pamphlet issued by Watson E. Coleman, 644 G. St., N. W., Washington, D. C., which tells the cost of procuring a patent and how to proceed, requirements as to drawings or models and gives valuable pointers on the status of joint inventors, causes of rejections, trade-marks, copyrights, protecting patents and sale and assignment of patents. Copies may be had by those interested in the subject by writing to Mr. Coleman.

Catalog Notes

IN THE LATEST edition of the Walworth Log, issued by the Walworth Company, Boston, Mass., is an interesting article describing the Kelly & Jones Company's Greenburg factory, which has recently been purchased by the Walworth Company. The land area of this factory covers 31 acres and the factory floor 16 acres. The entire issue is devoted to halftones and description of this factory. This issue of the Log will be found interesting to readers who wish to know more about the manufacture of pipe, valves and fittings.

QUIGLEY FURNACE Specialties Co., Inc., 26 Cortlandt St., New York City, is sending out a pamphlet describing its Triple-A solutions for preventing corrosion of iron, steel and other metals. Examples are shown of corrosion which has taken place beneath successive coats of paint on ocean liners and water screens. The Quigley solutions, which are compounded from coal-tar derivatives, are described, as a permanent protective coating against alkalis and water and a resistive coating against acids, for metals and for concrete, to which they can be applied without sizing. Colors available and equipment for which use has been made are given in the pamphlet which can be had from the Quigley Co. on request.

BRISTOL'S MECHANICAL motion and electrical operation recorders are described in Catalog 1600, recently issued by the Bristol Co. of Waterbury, Conn. These recorders are designed to furnish automatic records of mechanical operations and are built in two types. The mechanical motion recorder gives a record of the time of operation and the extent of mechanical movement. Its principle of operation is entirely mechanical. The electrical operation recorder is operated electrically and, in contrast to the mechanical motion recorder, it records the fact of operation, time of operation and the duration of movement. Either of these recorders may be furnished to give round or strip charts. They are applicable to various kinds of machinery, elevators, hoists, conveyors, opening and closing doors, gate valves, etc.

MANUALLY AND electrically operated oil circuit breakers, types D, F-1, F-2, and F-3 manufactured by the Westinghouse Electric and Manufacturing Co., are described in a new leaflet recently issued. The types D and F oil circuit breakers described in this leaflet comprise a complete line of moderate capacity, non-automatic and automatic, manually and electrically operated outdoor circuit breakers. The construction of the tanks, tank linings, mechanism and contacts is fully described, an account being given of the distinctive features of both the outdoor and subway types.

TYPE CL CARBON circuit breakers designed especially for 250-v. industrial applications where a compact breaker is required, are described in full in a new publication recently issued by the Westinghouse Electric and Manufacturing Co. This publication, circular 1705-A, contains a detailed description of this rigid, yet attractively constructed breaker. It points out the functions of the breaker contacts, and outlines its characteristic of effective shock absorption, adjustment and equalization of brush pressure, overload attachments and other points of interest in the carbon circuit breaker.

MATERIAL, DESIGN and Construction of Steam Jet Ash Conveyors is the name of a 24-page bulletin that has just been issued by the United Conveyor Corporation, Chicago, written especially for the operating engineer, superintendent and manager of power plants, architects and consulting engineers and all concerned with the clean and economical disposal of ashes, as well as with the upkeep and maintenance of ash-handling equipment.

UP-TO-DATE discussion of the design and applications of centrifugal pumps is presented in a fully illustrated 72-page book issued by the DeLaval Steam Turbine Co. of Trenton, N. J. This describes centrifugal pumps of the single stage and multistage types for power plant, water works, drainage, hydraulic pressure and other services; for high efficiency, high head and high speed, with two-part casing split in the plane of the shaft axis.

These pumps are made to limit gages so that renewal parts, supplied by the factory, can be inserted by the customer without having to be fitted. Centrifugal pumps are now built to have efficiencies exceeding 87 per cent and with characteristics such that the load on the driving motor

decreases rather than increases when a given discharge is exceeded, thus protecting the motor against overload. Combined with geared steam turbines, centrifugal pumps are used for water works service giving high duty. Engineers who have to do with the pumping of water, whether against low or high heads or in small or large quantities should find much of interest in this publication.

AMERICAN ENGINEERING Co. has just issued a catalog describing the new Taylor stoker. This catalog contains a section on the use of preheated air for which the new type of Taylor stoker has been developed and a description of the stoker's distributing ram system which makes it possible to vary the volume of the retort to suit the burning characteristics of different kinds of coal. Illustrations are given of the new Edgar Station of the Boston Edison Co., the Kearny Station and the Saginaw River plant of the Consumers Power Co., which operates normally at 350 per cent of boiler rating with peaks up to 600 per cent. An illustration is also given of the new Richmond Station of the Philadelphia Electric Co. and numerous stoker installations in industrial plants are also shown. A copy of this catalog may be had by addressing the American Engineering Co., Philadelphia, Pa.

THE GAS PRODUCTS ASSOCIATION, 140 So. Dearborn St., Chicago, Ill., is distributing a pamphlet describing the standards of hose connections for welding and cutting torches and regulators, which have been developed by the Standardization Committee of the association and approved by the International Acetylene Association and the Underwriters' Laboratories, Inc. These standards have been adopted by the leading manufacturers of this equipment.

LE VALLEY carbon brushes for generators, motors and all stationary machines are treated in Catalog No. 7 recently published by the Le Valley Vitae Carbon Brush Co., of New York City. Besides giving the dimensions, prices and illustrations of the various kinds and shapes of brushes manufactured, the catalog contains a table giving in condensed form the general characteristics of carbon brushes and their influence on performance.

AUTOMATIC VOLTAGE REGULATORS are made the subject of Bulletin GEA-123, which has recently been published by the General Electric Co. In this bulletin are illustrated and described a number of automatic generator voltage regulators, which are manufactured by the General Electric Co. The cycle of operation, connections employed, application and construction of the different types are treated in this bulletin.

CHICAGO FUSE MFG. Co. has recently published an eight-page pamphlet, describing and listing the ferrule contact and knife-blade contact "Union" renewable fuses. The fuses listed include sizes from 1 to 60 amp. for the ferrule contact type, and 65 to 600 for the knife-blade contact type, 250 or 600 v.

GRINDLE UNIT PULVERIZERS are described in Bulletin No. 7 just issued by Grindle Fuel Equipment Co., a subsidiary of Whiting Corporation, Harvey, Ill. The bulletin describes the general construction, features and methods of operation of this unit pulverizer and shows several typical installations of it.

A REVISED publication recently has been issued by the Westinghouse Electric and Manufacturing Co. on static condensers, which covers the subject of losses due to low power factor, their correction, and the economic application of static condensers.

YEOMANS AUTOMATIC electric junior drainage pump is described in leaflet B-330, which has just been issued by Yeomans Brothers Co., Chicago, Ill.

BALL AND ROLLER BEARING motors are described in Bulletin 4000, recently issued by The Reliance Electric & Engineering Co., Cleveland, Ohio.

SPRAY AIR FILTERS is the subject of Catalog 459, recently issued by the Spray Engineering Co., Boston, Mass. The bulletin gives the application, general principles and construction of these filters, together with notes on erection and operation.

BULLETIN No. 812, recently issued by the Electric Machinery Manufacturing Co., of Minneapolis, Minn., deals specifically with belted synchronous motors, describing in detail many of the features of construction which make these motors dependable.

UEHLING INSTRUMENT Co. of Paterson, N. J., has just issued new Bulletins 118 and 118-A describing the Apex CO_2 recorder and indicator. These instruments operate on the orifice principle and do not employ chemical solutions, the principle being fully explained in the bulletins.

AMES UNIT system of fuel oil pumping, heating and straining with automatic temperature and pressure control is the subject of a bulletin recently issued as specification No. 102 by the Ames Pump & Machinery Corporation of New York City.

GREENFIELD TAP & DIE CORP., Greenfield, Mass., has recently issued its general catalog No. 49, dealing with small tools manufactured by this company. Copies may be had by anyone interested by writing the company at its home office.

CLEVELAND ELECTRIC TRAMRAILS are illustrated in a booklet recently issued by the Cleveland Crane & Engineering Co., Wickliffe, Ohio. This little booklet was prepared to show the numerous applications of the Cleveland tramrail and how this equipment can be used to cut manufacturing costs.

THE FULTON "JUNIOR" feed water heaters, purifiers and receivers are described in a bulletin sent by The Fulton Foundry & Machine Co., Cleveland, O. The company has also issued a new bulletin describing the Fulton feed water heater and receiver and another describing the Fulton multiport exhaust head.

"CONCENTRATION IN BOILERS" by Grant D. Bradshaw, a paper read before the Engineering Society of Western Pennsylvania, is being reprinted and distributed by Andrews-Bradshaw Co., Pittsburgh, Pa. This paper discusses methods of determining boiler concentration and proper treatment to keep it at a low point.

LABORATORY STANDARDS is the title of Bulletin GEA-100 recently issued by the General Electric Co., Schenectady, N. Y. In this bulletin are illustrated and described the various instruments which are manufactured by the General Electric Co. for the exacting work encountered in industrial and research laboratories.

THE MERIT SYSTEM OF EDUCATION as adopted by the National Association of Stationary Engineers is discussed briefly in a bulletin recently sent out by the Chairman of the National Educational Committee of the N.A.S.E. Ten courses of study are offered, to be conducted by the question and answer method and those passing the courses are awarded either a technical certificate of merit or a practical certificate. Examinations are conducted by examining boards made up of members of the Association and members of the Association are eligible to apply for these courses.